FORESTS

UNITED STATES
DEPARTMENT OF AGRICULTURE

Forest Service

State and Private Forestry

Northeastern Area
and
Southern Region

Forest Health Monitoring

CROWN CONDITION

RATING GUIDE

Prepared by: Imants Millers, Entomologist, Durham NH; Robert Anderson, Pathologist, Asheville NC; William Burkman, Forester, Radnor PA; William Hoffard, Entomologist, Asheville NC.

April 8, 1992

UNITED STATES
DEPARTMENT OF AGRICULTURE

Forest Service

State and Private Forestry

Northeastern Area
and
Southern Region

Forest Health Monitoring

CROWN CONDITION RATING GUIDE

April 8, 1992

Prepared by: Imants Millers, Entomologist, Durham NH; Robert Anderson, Pathologist, Asheville NC; William Burkman, Forester, Radnor PA; William Hoffard, Entomologist, Asheville NC.

ABSTRACT

The Crown Condition Rating Guide is intended as a reference and source manual to instructors and users of the crown rating data in the Forest Health Monitoring program and similar applications. The Guide defines crown condition indicators, provides measurement units and methods of measurement, and expected changes and limitations of the measurements. The crown condition indicators include crown position, live crown ratio, diameter, density, dieback, foliage transparency, and damage agents. Thus, it documents present crown rating methods for future interpretation in data analysis. The Visual Crown Rating model (VCR) is discussed briefly as an example of potential use of the crown rating data. A list of significant references is provided. The appendix contains current National Forest Health Monitoring field instructions, visual aids, and the VCR Model.

Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/crownconditionra00mill

CONTENTS

INTRODUCTION....1

CROWN CONDITION ASSESSMENT....2-22
- CROWN DESCRIPTION....2
  - Definition....2
  - Crown Form....3
  - Top of Crown....4
  - Base of Crown....4
  - Sides of Crown....4
  - Branch....6

- CROWN CONDITION INDICATORS....7-22
  - Crown Position....7
  - Live Crown Ratio....10
  - Crown Diameter....12
  - Crown Density....14
  - Crown Dieback....16
  - Foliage Transparency....19
  - Visual Damage Symptoms....21
  - Summary....22

DATA QUALITY CONTROL....23-27
- MEASUREMENT UNITS AND PRECISION OBJECTIVES....23
- TRAINING....24
- VISUAL AIDS....25
- FIELD PROCEDURES....26
- REMEASUREMENTS....27

VISUAL CROWN RATING (VCR) MODEL....28-29

BACKGROUND LITERATURE....30-31

APPENDIXES....32-37
- I....32
- II....33
- III....36

INTRODUCTION

Forest trees are shaped by a multitude of abiotic and biotic influences. Individual tree vigor and growth are determined by physiological age and available water, nutrients, and light resources at a site. Climate and site conditions affect resource availability, but a tree's position relative to its neighbors is critical in determining the amount of water, light, and nutrients available for any one tree. These tree-stand interactions make it necessary to collect stand-level data as well as individual tree data.

Crown evaluations describe the condition of a tree as seen by the observer. An observed tree condition is a combination of past and present conditions expressed by the tree. The size and density of the crown may be primarily the result of past growth processes, influenced by site, stand density, and external extended stresses. Defoliation and damage in the crown reflect current stresses. Therefore, crown evaluations that quantitatively assess current tree condition are really an integrated measure of site, stand density, and external stresses from the past and present.

Purpose of the Guide

Measurements of crown vigor indicators are important for the determination of tree health. For our purposes tree health is defined as the normal expected growth and appearance of a tree. The crown condition indicators are used in an attempt to quantify tree health, but the importance of any of the indicator will depend on the expectations of the data user. This manual is prepared for anyone desiring to apply crown rating methods used in Forest Health Monitoring and to serve as a tool of standardization and documentation of methods. Remeasurements in the North American Maple Project and in National Forest Health Monitoring have shown that major variations in measurements between individuals occur because of differences in the understanding of definitions.

This manual is prepared using the procedures outlined in the National Forest Health Monitoring Field Measurement Guide. These guidelines are designed for field crews collecting field measurements in the permanent plots of the Forest Health Monitoring Detection Program and for similar applications. The Crown Rating Manual describes the tree crown as defined for rating purposes, the measurement units, and discusses in detail each one of the five crown vigor indicators: crown diameter, crown ratio, crown density, crown dieback, and foliage transparency. Foliage retention for a few conifers were used in 1990 and 1991, but later were discontinued because of poor repeatability of estimates.

The crown damage symptoms are discussed briefly, but the coding and definitions are provided in the appendix.

The Visual Crown Rating (VCR) Model is presented in the appendix to show how a combination of the crown measurements may be used to describe tree health.

CROWN CONDITION ASSESSMENT

The tree crown may be described in many ways. The greatest variation in assessing crown conditions usually is in differences of interpretation of the crown. Uniformity in crown description is of utmost importance when various measurements are taken to determine the health of tree.

CROWN DESCRIPTION

The following section defines the crown and highlights critical points for crown condition indicator measurements.

Definition

The crown of a tree is the foliated area supported by a single stem, the trunk or bole. The crown includes the crown stem, branches, twigs and buds, seeds and cones, and foliage. Normally, the dead lower branches are excluded from crown measurements. When a dead upper crown is present, it may or may not be included as part of the crown. The specific crown condition indicator definition must be consulted. The following discussion describes in detail the major parts of the crown as used in the crown condition assessments. All the crown condition indicators assume a 2-dimensional crown as visible to an observer (Fig. 1). All indicators assume a vertical crown plane, except crown diameter which is measured on a horizontal plane.

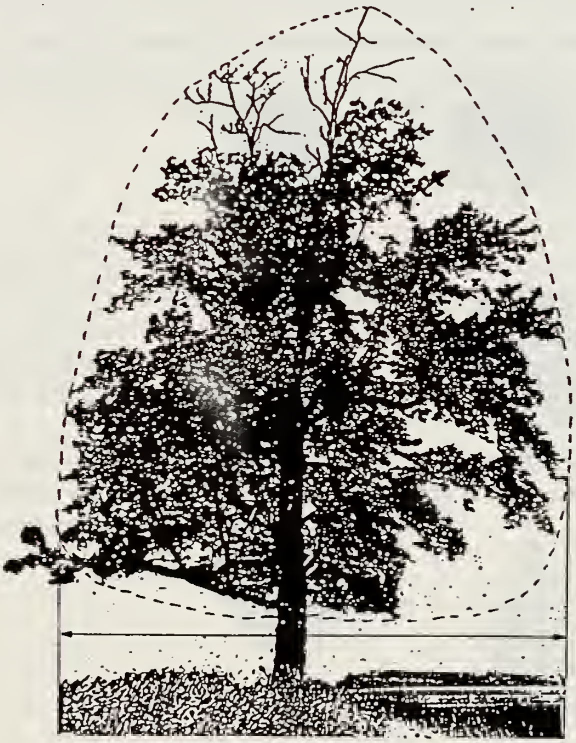


Figure 1. Sugar maple. The dotted lines show the crown outline for crown density determination; 59 percent of the crown area is black (60% density).

Crown Form

The crown form of open grown trees is characteristic for a species. However, in a stand, the form usually is modified because of competition and past damage. For the purpose of crown density assessment, the general form of a normal forest grown tree in the stand will be determined and placed in one of the following classes (Fig. 2):

1. Round (Fig. 2a)- the crown appears completely round (e.g., mature apple); with age and competition, these crowns tend to flatten to disc shape.
2. Oval (Fig. 2b) - the crown appears to be football shaped; most hardwoods; with age crowns of these trees tend to become round.
3. Rectangular (Fig. 2c) - the crown is a rectangle with rounded corners.
4. Rounded triangle (Fig. 2d) - the crown is oval shaped at the top, but approaches triangular shape in lower half; frequently, young conifers have pointed tops, but become rounded with age.
5. Pyramid (Fig. 2e) - most young conifers have triangular shapes, like a christmas tree.
6. Vase (Fig. 2f) - the top of the tree tends to be wide and flat, while the base narrows toward the trunk.

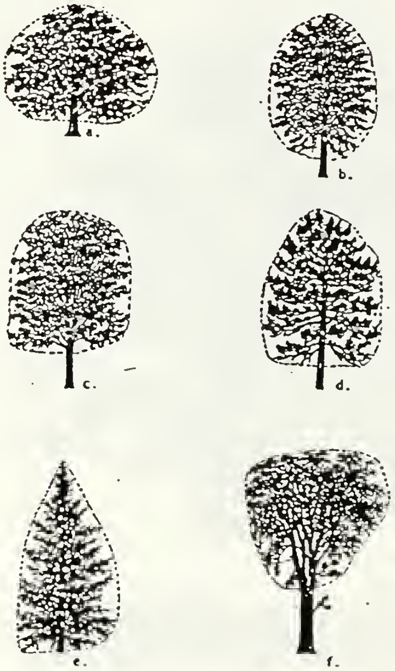


Figure 2. Common crown shapes: a. round; b. oval; c. rectangular; d. rounded triangle; e. pyramid; and, f. vase.

Top of Crown

The top of the crown is the highest point of a standing tree. Younger trees usually have conical shaped crowns, with the terminal coming to a point (Fig. 2e). Older trees and many hardwoods have globose and flat-topped crowns where one or more lateral branches may be at the highest point (Fig. 2c,f). For some measurements only the highest live branch is considered, while other measurements include the dead top.

Base of Crown

The base of the crown here is defined as the lowest live part of the crown. Most of the measurements define the live base of the crown by drawing a horizontal line from the bottom of the lowest branch of the obvious crown, usually the largest branches at the bottom of the crown (Fig. 3, shown with solid line). Thus, the base of the branch may be above or below this line. Then, if any branches above 1-inch diameter are within 5 feet below this line, the base is moved to the base of that branch, and the process is continued until no branches are found within 5 ft. The base of the crown then is horizontal line at the bottom of the foliage of the lowest qualifying branch. The intent here is to include most of the branches in the crown, but to exclude epicormic shoots and straggler branches that usually do not contribute much to the growth of the tree.

Occasionally, all the original major crown branches are dead or broken and abundance of new branches are developing. At first, before branches reach the 1-inch diameter size, technically, the tree has no crown. When the new branches reach the 1-inch diameter limit a new crown is forming. The previous obvious base of the crown here would be the dead branches, while many of the live branches with foliage may be below. The recommendation is to find the line for the lowest branches (1-inch diameter or larger) that meet the 5-ft rule. These situations are likely to occur in areas of heavy thinning, commercial clearcuts, and severe weather damage.

Sides of the Crown:

For crown density the perimeter is assumed to be the appropriate crown form, which is bilaterally symmetrical to the viewer. The lateral sides of a crown used to estimate density are drawn from branch tip to branch tip of dominant branches (Fig. 2). Shading and competition from neighboring trees usually are responsible for missing portions of the crown. For example, two trees growing close together have crowns that have one side, the common side, without branches. Large gaps between branches frequently are the result of broken branches.

Foliage transparency estimates exclude large spaces between branches and within the crown where foliage is not expected to be present (Fig. 7). Thus, the side of the crown is determined by drawing a line around the outer margins of all the large branches.

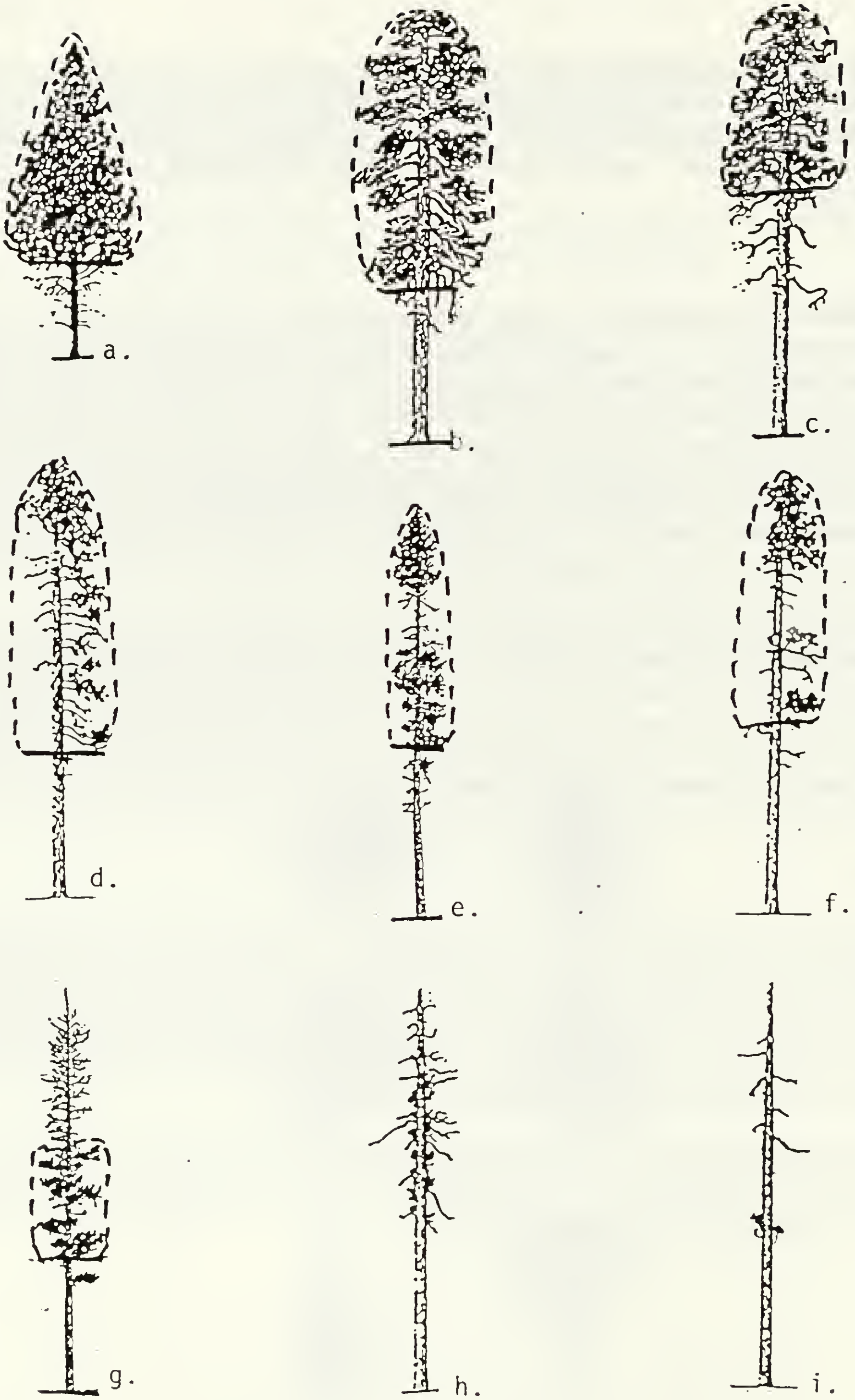


Figure 3. Crown outlines for a variety of tree conditions.

Branch

A live branch here is defined as any woody lateral growth supporting foliage and larger than 1 inch at the base just above the swelling where it joins the main stem. Dead branches have no minimum size to be included for dieback estimates. Lower dead branches are not considered as part of live crown. Dead upper crown branches without twigs (less than 1-inch diameter) are considered as old dead, or snag branches, and are not included in the dieback estimates, but are included in crown density estimates.

Secondary growth, less than 1-inch diameter, such as water sprouts or suckers are excluded. Occasionally, difficulties are encountered when trees in a stand are suddenly released or damaged by destructive agents. The large branches may die as a result of the shock and new sprouts develop along the trunk (Fig. 3h and i). For a few years, the tree may have dense foliage, but by definition no crown. *These unusual conditions may be identified in the data sets from a combination of crown condition indicators such as 0 crown ratio, 0 crown density, 0 crown diameter, 99 crown dieback and 99 for foliage transparency.*

CROWN CONDITION INDICATORS

Six crown condition indicators are used to assess the health, or vigor of trees in Forest Health Monitoring:

1. Crown position
2. Crown diameter
3. Live crown ratio
4. Crown density
5. Crown dieback
6. Foliage transparency

Crown Position

Crown position is a standard forest classification method used in the United States.

Definition

Crown position class rating describes tree vigor in relation to sunlight received and a tree's position in relation to the neighboring trees. The following 5 classes are defined as follows (Fig. 4):

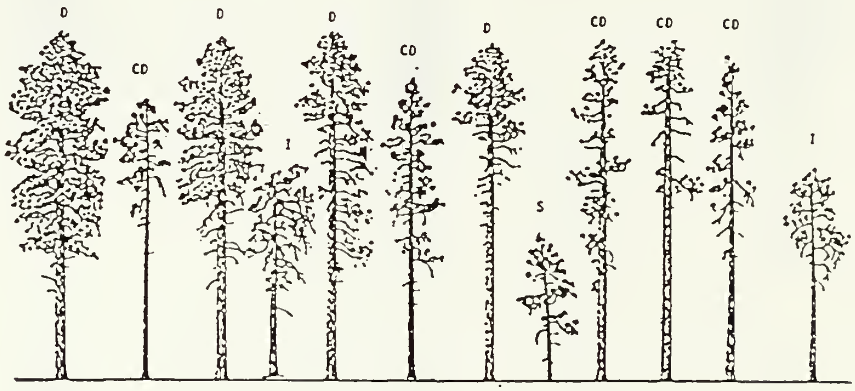


Figure 4. Crown position of trees.

Code	*Class*	*Definition*
1	Open grown	Trees whose crowns have received full light from above and from sides throughout most of the tree's life, particularly during its early development period. Their crown forms or crown shapes have not been and are not likely to be influenced by other trees.
2	Dominant	Trees with crown extending above the general level of the crown canopy and receiving full light from above and partly from sides, larger than the average trees in the stand, and with crowns well developed, but possibly somewhat crowded on the sides.
3	Codominant	Trees with crowns forming the general level of the crown canopy and receiving full light from above, but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the side. (In stagnated stands, include trees with small-sized crowns crowded on the sides).
4	Intermediate	Trees shorter than those in the two preceding classes, but with crowns either below or extending into the crown canopy formed by dominant and codominant trees.
5	Suppressed	Trees with crowns entirely below the general level of crown canopy, receiving no direct light either from above or from the sides.

NOTE: Smaller trees on edge of stand and in small openings will be classified in the same class as similar size trees in the stand, recognizing that they receive more direct light than trees in the stand.

Biological Significance

Crown position is a good indicator of tree vigor. Open-grown, dominant, and co-dominant trees are more vigorous than intermediate and suppressed trees. However, the crown position reflects past performance rather than current condition. For example, a tree may be declining, yet still occupy upper canopy crown position until neighboring trees outgrow it.

Measurement

Unit: The subjective 5 crown position classes are the measurements.

Method of determination: Crown classification is done in the field. The crew interprets the definitions and apply them to the observed tree.

Expected precision: Remeasurement of 1990 New England Forest Health Monitoring field measurements gave following results: 96.5% remeasurements were within one class of the original measurements, but only 66.8% were exactly the same. None of the open-grown trees were rated the same in both measurements. Of particular importance is that 82.4% of upper canopy trees (open-grown, dominant and co-dominant) and lower canopy trees (intermediate and suppressed) were remeasured in the same crown canopy groups. Differences greater than 1 crown position class will be considered an error. The desired precision is to have remeasurements within 1 crown class nine out of ten times.

Limitations: The crown classification appears to work well within a fairly uniform forest stand without much recent disturbance. However, classification of crown classes in severely disturbed stands is difficult and repeatability between individuals is poor. Silvicultural practices, such as thinnings, timber stand improvement cuts, diameter limit cuts and similar stand manipulations, may change crown class of a tree just by the removal of its neighbor. Requirement for judgement on what the crown class was before disturbance introduces variability of judgement. How many years are required for tree in a disturbed situation to assume growth pattern of a normal tree in that crown class? For example, a suppressed tree surviving a clear-cut or a blowdown becomes dominant by definition, yet its growth may remain that of a suppressed tree for many years.

Causes For Change

Increase: A lower canopy tree may achieve upper crown position by loss of its neighboring upper crown trees, or by outgrowing its neighbors. Probable causes for the loss of the adjacent trees are weather, insect and disease damage, and silvicultural practices.

Decrease: The most common loss of upper canopy position is the result of injury that reduces height growth and allows lower canopy trees to over-take it. A normal change occurs in a transition forest when short-lived trees reach maturity and are outgrown by longer-lived trees that are continuing vigorous height growth.

Persistence: Crown position class changes usually are slow requiring many years. Occasionally, more rapid change may occur when natural disasters strike and result in major stand disruption. Of course, tree harvesting also creates stand disruption, where upper canopy trees are removed and lower canopy trees become upper canopy trees by definition.

Intended Use

Crown classes usually are used to indicate growth vigor of the tree. The upper canopy trees are expected to grow faster than the lower canopy trees. However, some tolerant lower canopy trees are expected to achieve upper canopy status sometime in the future.

Shared Attributes With Other Indicators

None of the measured attributes are shared directly. However, measurements affected by stand density are likely to be included here. For example, crown diameter is likely to decrease as a tree crown class changes from open grown, to dominant, to codominant. Similar change probably occurs with crown ratio.

Live Crown Ratio

Live crown ratio frequently is used for research purposes to predict growth potential of trees.

Definition

Live crown ratio is the percent of total tree height that supports live foliage (Fig. 5). Dead top is excluded from tree height. Likewise, dead lower branches are not included as part of the live crown.

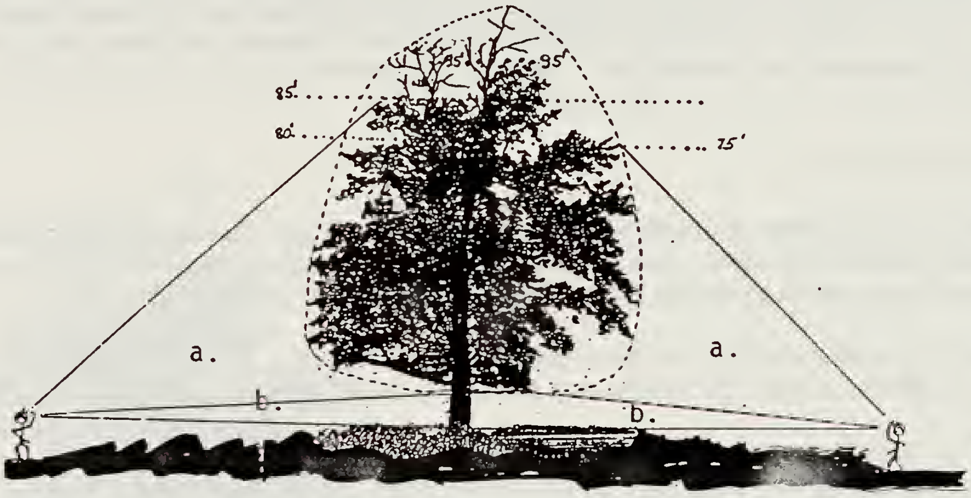


Figure 5. Estimating live crown ratio; a. height of live crown; b. height of trunk; live crown ratio = a /(a+b) x 100.

Biological Significance

Live crown ratio provides a tree vigor estimate to predict future growth in diameter when measured at breast height (4.5 ft). Large crown trees, that is, large live crown ratio values indicate better growth than a small live crown ratio value.

Measurement

Units: Live crown ratio is recorded in 21 5-percent classes (Table 1). The highest class, 100%, is recorded with 99 class code. A tree with no obvious crown (epicormic shoots only; no live branches larger than 1 inch at base) is recorded as having 0 crown ratio.

Method of determination: The live crown ratio is determined by the ratio of crown length to total height of the tree (Fig. 5). Crown length is determined from the top upper-most live branch to the base of the crown. Dead branches above the live crown are not included in the ratio estimate. For some forestry purposes, branches are visually transposed from lower crown to fill gaps at middle and upper crown. This is not done in this procedure.

Live crown ratio will be done by two persons located in the opposite sides of the tree (Fig. 5). The persons will step back about 1/2 to 1 tree length from the base of the tree and move sideways at least 10 ft to obtain a good view of the crown. It is very likely that for rounded top trees lateral branches will block the highest branch, and therefore, the two persons may disagree on the height of the top of the tree.

When the two persons disagree in their estimates, they will discuss their reasons for their rating. Either one will change a rating or an average will be struck and the class of the estimate will be recorded.

Expected precision: Variation in measurements between observers and remeasurements of two classes or less, a maximum of 10 percent, are considered normal. Greater variation is an error. Data are acceptable when error rate does not exceed 10 percent of the measurements. Most of the errors occur when the whole crown can not be adequately observed.

Limitations: Measurement errors may occur from several sources. The top of the tree may not be clearly visible, or when rounded, clearly identifiable. The branch structure of some trees is such that a clear 'obvious' base of the crown is difficult to establish. One also should be aware that a small, 5 in. d.b.h. tree, such as hemlock after a clear-cut, might have a high crown ratio, while a large oak in a dense stand may have a small crown ratio.

Causes For Change

Increase: The maturation of epicormic branches below the crown fills-in growing space created by the loss of neighboring trees. As these branches increase in size the base of the crown is lowered. Annual terminal growth increases crown length if lower branches do not die.

Decrease: Live crown ratio may decline from a multitude of reasons. The base of the crown may move upward or the top is lost, thus decreasing the crown length. Common causes for this are:

1. Self-pruning with increasing age; characteristic of a species.
2. Shading from neighboring trees as the result of increasing crown closure.
3. Mechanical damage from adjoining tree branches.
4. Defoliation caused loss of lower branches.
5. Loss of top of the tree from breakage or mortality.

Persistence: Live crown ratio normally changes slowly and the usual trend is to decline, unless some mechanical pruning or damage occurred. Changes may go in either direction. Increasing stand density is likely to reduce live crown ratio, while opening of a stand, coupled with vigorous growth could increase the ratio. Live crown ratio increase is less likely with advanced maturity of trees.

Intended Use

Live crown ratio is associated with tree vigor and d.b.h. growth. The larger the ratio, the greater is diameter growth. The reduction of growth with declining crown ratio may be the result of increased distance between the bottom of the live crown and the d.b.h. area where growth is measured. It is known that diameter growth declines as this distance increases.

Shared Attributes With Other Indicators

None of the live crown ratio attributes are included in the other crown measurements. However, the base line set in live crown ratio is shared for density, dieback, and transparency.

Crown Diameter

Crown diameter is commonly used to assess living space and growth potential of trees.

Definition

Crown diameter is the average horizontal distance between widest point of the crown and its perpendicular axis measured on the ground at the drip-line of branch tips and through the center of the bole. When an unusually long branch occurs on a side of tree, the next longest branch is chosen (Fig. 6). A leaning tree may be measured through an assumed center of the crown.

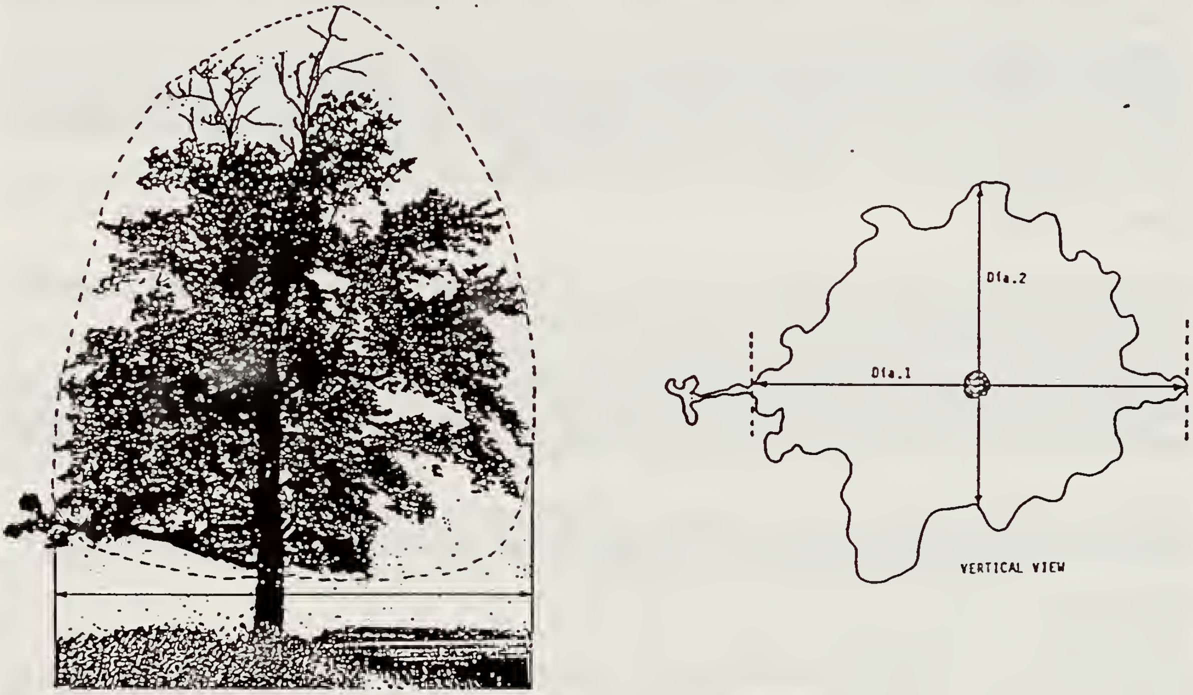


Figure 6. Crown diameter of a tree; reduce the length of the extra long left side branch; measure the diameter and its perpendicular diameter, add the two and divide by two; (Dia.1 + Dia.2) / 2 = average diameter.

Biological Significance

Crown diameter is another indicator of tree vigor. Larger diameter trees are expected to have greater growth than small crown diameter trees. Crown diameters tend to be species specific, and therefore, growth predictions based on crown diameter alone between species are not proper.

Measurement

Unit: Crown diameter is measured to the nearest 1 ft.

Method of determination: Crown diameter is measured with a tape measure on the ground. The first measurement is the widest axis from branch tip to branch tip, and the second measurement is a similar measurement at right angle of the first. The two measurements are recorded and then the average crown width is determined later. Most errors occur from misjudgement of the vertical line from the branch tips. A weight hanging on a string, such as compass, raised to point at the branch may be used to establish the vertical line down from branch tips.

Expected precision: The average crown diameter remeasurement must be within 3 ft. of the original measurement to be considered acceptable. Greater differences are considered errors, however, a third measurement is required to determine which of the first two measurements were in error. The data are considered acceptable when error frequency is 10 percent or less for all the measurements.

Limitations: Measurement errors may occur from several sources. The most common causes of error is improper determination of vertical angle from the branch to the ground level, and improper selection of the widest axis of the crown. The side branches may be intermingled with the neighboring trees, or shielded by lower canopy, making difficult to determine the end of the branch.

Causes For Change

Increase: Crown diameters are likely to increase as a tree assumes higher canopy position, and also, with decreasing stand density where space is available for lateral branch growth.

Decrease: Crown diameters decline with increased competition with neighboring trees. Mortality of lower branches from competition, snow and ice damage, or insect or disease damage reduces crown diameter. Shock response after logging and similar disturbance may result in loss of large branches.

Persistence: Crown diameters are not likely to change from one year to the next, unless some injury has occurred. Measurements every 5 to 10 years may be needed to detect significant changes.

Intended Use

Crown diameters are probably associated with vigor and d.b.h. growth of most species. Data is available that shows a good correlation for loblolly and shortleaf pine. Simply, the larger the crown, the more growth is expected. This assumption may not be valid for mature and overmature trees that have slowed growth, but may be developing wider, short crown ratio trees. Data are needed to compare young and old trees of various species.

Shared Attributes With Other Indicators

Crown diameter measurements are shared occasionally with crown density measurements. When two trees are close together, one side tends to have reduced or even a non-existent crown. As a result one crown measurement may be one half of normal. A similar reduction is recorded in crown density for the missing one-half of the crown. Indirectly, crown diameters are shared with crown class because of the stand density relationship.

Crown Density

Crown density measurement was developed in the southern U.S. on loblolly and shortleaf pines to predict growth potential and tree vigor.

Definition

Crown density represents the amount of branches, foliage, and reproductive structures that block light visibility through the crown (Fig. 1). The crown for this estimate is bilaterally symmetrical perimeter of the live and dead branches including spaces between branches and large open areas in crown. A dead top is part of the crown, but dead lower branches are excluded.

Biological Significance

Crown density estimates the condition of the tree crown in relation to a normal, healthy forest grown tree and also is an indicator of expected growth in the near future. Each species of tree has a normal crown that will vary with the species, site, genetics, tree damage and etc. The method was developed on loblolly and shortleaf pines, where growth correlations were observed.

Higher crown density estimates are correlated with faster growth, while lower crown density measures are correlated with slower growth.

Measurement

Units: Crown density is recorded in 21 5-percent classes (Table 1). The recorded value is the average of two observers from opposite sides of the tree, upgraded to the next full 5-percent class. The lowest class, 0% is recorded when the tree does not have a defined crown, that is, the trunk is alive as indicated by small twigs, but no live branches are larger than 1 inch at the base. The highest class, 100%, is recorded with the 99 code.

Method of determination: Crown density rating is accomplished with two persons located on the opposite sides of the tree. Individuals should be positioned about one tree length away from the tree where you can get a good view of the crown. To determine the crown outline, select the point on a stem used for crown ratio and project a normal crown for that tree. Foliage below the crown base is not included in the crown. Project half-sided trees as full crowns, and include crown dieback and open areas in this outline (Fig.1).

After determining the outline, the two persons should hold the density card under the crown and estimate what percent of the outlined area is blocking sunlight.

Expected precision: Recorded measurements must be within 2 percentage classes (approx. 10%) when remeasured. Greater differences are considered errors, however, a third measurement is required to determine which measurement is in error. The error frequency must be 10% or less for the data to be acceptable, unless confirmation is made that the original measurements were correct, that is, the remeasurement was in error.

Limitations: Measurement errors may occur from several sources. The major cause of variation is the assumed normal crown of the tree and then the estimated branch area missing, particularly, for trees closely adjoining another tree. The top of the tree or sides may not be clearly visible at the same time and errors may occur from 'piecing the crown together' from various viewing points. The branch structure of some trees is such that a clear 'obvious' base of the crown is difficult to establish.

Causes For Change

Increase: Normally, crown density is expected to decline over time as a result of competition in the stands and aging of the tree. Occasionally, however, crown density may improve, that is increase, when disturbances in the stand occur:

1. Increased growing space as a result of death or removal of neighboring trees.
2. Rebuilding crown structure after loss of major branches.
3. Increased foliage after a poor foliage year.
4. Loss of branches causing re-definition of crown perimeter, such as dead branches in the top of the tree, or death of widely separated branches in the lower crown.

Decrease: Crown density is likely to decline from various damages, changes in stand density, and reduced growth associated with aging:

1. Loss of branches from mortality or breakage, creating gaps in the crown.
2. Increased transparency from poor foliage production, or from defoliation.
3. Shading of branches by neighboring trees when stand density increases.
4. Foliage stunting that accompanies injury, or follows refoliation.
5. Crown form changes as a result of increased stand density.
6. Gaps increase with age of trees.

Persistence: Crown density usually changes slowly as the stand density changes. Defoliation may change crown density within a growing season, but repeated defoliation followed by branch dieback is needed for permanent change in crown density. Branch mortality, such as wind and ice damage creates rapid change in crown density.

Intended Use

Crown density is associated with vigor and diameter growth at breast height of loblolly and shortleaf pine. Although not confirmed, one suspects that crown density has similar relationships with growth for all trees. Although the measurements are recorded in 5-percent classes, the most likely use of the data are broader groupings to indicate good, average and poor crown conditions.

Shared Attributes With Other Indicators

Crown density includes several other crown characteristics measured separately:

1. Foliage transparency as influenced by changes in foliage abundance; however, the woody parts, branches and twigs remain to reduce light penetration.
2. Crown dieback as reflected by complete absence of foliage.
3. Crown diameter as influenced by competition from adjacent trees.

Crown Dieback

Crown dieback estimates have been used to estimate stress impacts on trees.

Definition

Crown dieback is defined as branch mortality that begins at the terminal portion of branch and proceeds toward trunk (Fig. 3g, h, i; and Fig. 7). When whole branches are dead in the upper crown, without obvious signs of damage such as animal damage or breakage, it is assumed to have died from the terminal down. Large dead branches without fine twigs (less than 1-inch branches) are snag branches, or old dead branches and are not included as crown dieback. Dead branches in the center and lower crown or below the live crown are assumed to have died from competition or shading and are not considered as crown dieback.

Biological Significance

Crown dieback is frequently thought of as a symptom that results from severe stress or a combination of stresses. However, some crown dieback results from normal tree growth, such as, excessive seed production. Thus light crown dieback, probably does not indicate abnormal condition. Some species of trees, particularly conifers, do not exhibit crown dieback conditions unless something is seriously wrong with the root system.

Measurement

Units: Crown dieback is recorded in 21 5-percent classes (Table 1). The "0" class indicates total absence of dieback. One dead twig seen in the crown is recorded in the 5-percent class. When all the branches are dead, but the tree is still alive, the 99 code is recorded.

Method of determination: First, the observer draws a two dimensional outline of the crown (Fig. 7). NOTE: THE PERIMETER OF THE CROWN FOLLOWS OUTLINE OF THE LARGE BRANCHES AND EXCLUDES LARGE OPEN AREAS AND SPACES BETWEEN BRANCHES. Then, the proportion of the crown with dieback is blocked out. Finally, the proportion of the dieback area in relation to the whole crown is determined. Large dead branches without small twigs, that is snag branches, are excluded from dieback measurement.

Crown rating is done by two persons located in the opposite sides of the tree. The persons will step back about 1/2 to 1 tree length from the base of the tree and move sideways at least 10 ft to obtain a good view of the crown. When the two persons disagree in their estimates, they will discuss their reasons for their rating. Either one will change a rating or an average will be struck and the class of the estimate will be recorded. The differences may be due to differences in crown conditions, the estimate of the person, or both.

Binoculars should be used to assist in the data collection. Observers should be conscious of lighting conditions and how that affects the day's observations. Under limited light conditions the observers should take extra time because poor lighting can make the measurement more difficult.

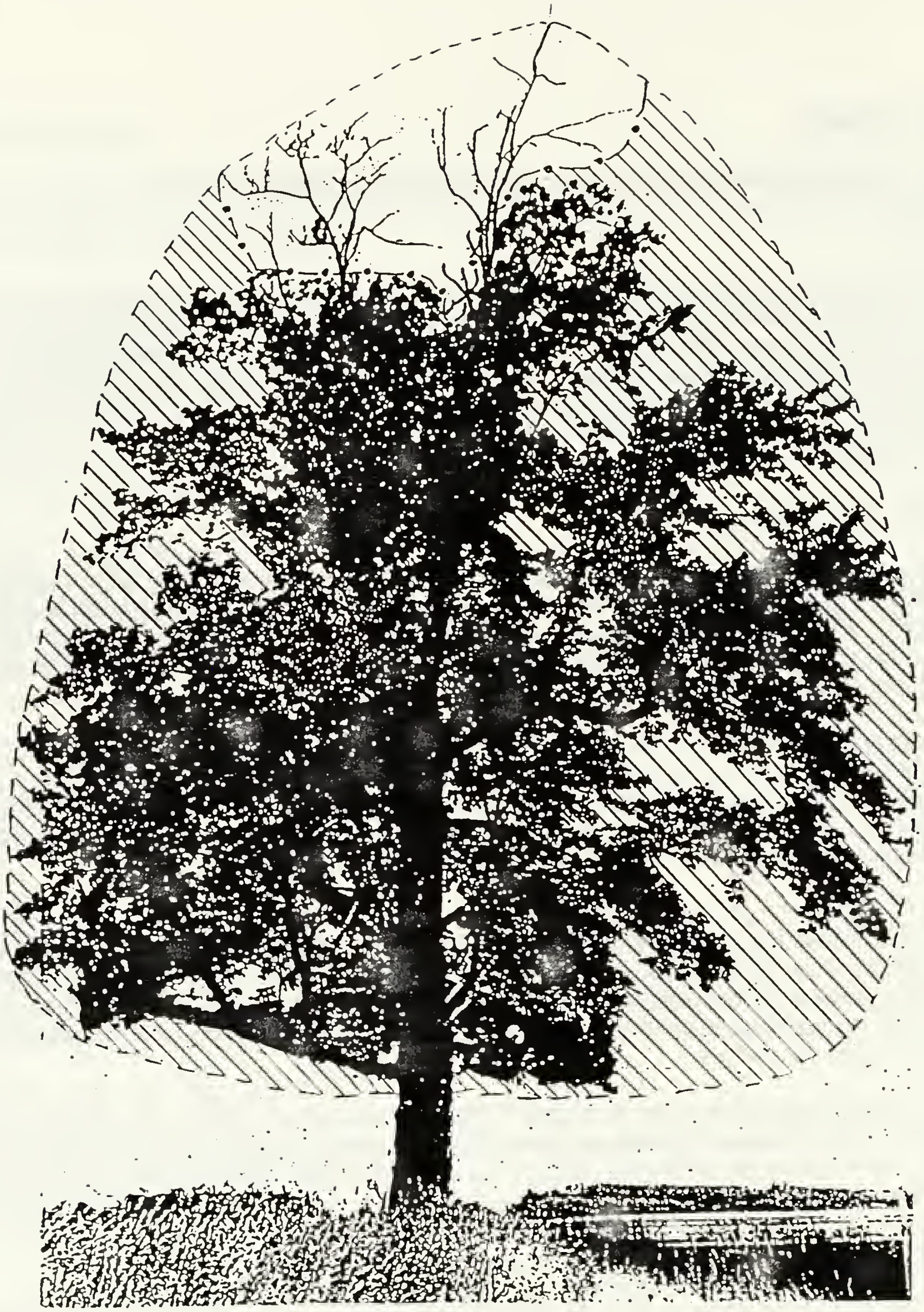


Figure 7. Sugar maple crown. Crown dieback is 9% of total crown area (10% class); Striped areas are open areas of crown that are not included for transparency estimate; foliage transparency is 11% (15% class).

Expected precision: Recorded measurements must be within 2 percentage classes (approx. 10%) when remeasured. Greater differences are considered errors, however, a third measurement is required to determine which measurement is in error. The error frequency must be 10% or less for the data to be acceptable, unless confirmation is made that the original measurements were correct, that is, the remeasurement was in error.

Limitations: Measurement errors may occur from several sources. The top of the tree may not be clearly visible, or when rounded, clearly identifiable. The branch structure of some trees is such that a clear 'obvious' base of the crown is difficult to establish. Heavy defoliation, transparency greater than 50%, makes it difficult to separate dead twigs and branches from living, defoliated branches.

Causes For Change

Increase: Crown dieback is a disease symptom showing tree's response to severe stresses. It may be initiated from damage to the roots, damage on the trunk that interferes with liquid transport to the crown, and direct injury in the crown. Complete defoliation of evergreen conifer twigs is likely to cause immediate crown dieback. Likewise, some hardwoods respond to severe defoliation with dieback, but time of growing season when it occurs seems to be important. Excessive seed production on some species causes dieback of small twigs. Frequently, hardwoods suddenly released from competition, such as after logging, exhibit crown dieback. Few hardwoods left after a commercial clearcut may undergo a period of severe crown dieback.

Decrease: The only way that crown dieback can decrease is through the loss of the dead twigs and branches. Trees frequently rebuild their crowns after crown dieback unless continuation or additional new stresses cause death of trees.

Persistence: Small dead twigs do not persist very long, and may drop annually. Larger dead branches persist longer. Therefore, annual fluctuations of dieback are expected, unless severe stresses cause large branch mortality that requires many years of recovery.

Intended Use

Crown dieback estimates reflect the severity of recent stresses on the tree. A tree with increasing dieback is likely to reduce its growth. However, a tree may be recovering from past stresses as growing conditions improve. Therefore, the measurement serves as an early indicator of tree response to environmental stresses or damage. The probable use of the measurements is an aggregation into crown dieback severity classes.

Shared Attributes With Other Indicators

None of the other attributes are included in the crown dieback measurements. Crown dieback, however, is included in the crown density measurement. Extent of crown dieback may effect crown ratio, because of loss of top of crown.

Foliage Transparency

Foliage transparency was created in the North American Sugar Maple Decline Project to measure insect and disease caused defoliation. Later, it was adapted to National Forest Health Monitoring for measuring all species of trees.

Definition

Foliage transparency is defined as the amount of skylight visible through the foliated portion of the crown or branch (Fig. 7). The dead parts of crown are excluded. The crown perimeter is a line following the contours of major branches, excluding the large gaps between branches. Likewise, large open areas within the crown are excluded if foliage is not expected to occur there. Smaller similar openings are considered part of the foliage transparency estimate.

Biological Significance

Foliage transparency is an indicator of amount of foliage in a crown and thus related to prediction of growth. The crown for foliage transparency includes the live portion only; all dead areas are excluded. The average foliage transparency of healthy trees tends to be species specific.

Measurement

Units: Foliage transparency is recorded in 21 5-percent classes (Table 1). Foliage transparency is estimated from several sections of the crown and averaged. Complete defoliation is recorded with 99 code.

Method of determination: Crown rating will be done by two persons located in the opposite sides of the tree. The persons will step back about 1/2 to 1 tree length from the base of the tree and move sideways at least 10 ft to obtain a good view of the live crown (dieback areas are not included). First, the persons will draw a two dimensional outline of the crown. Second, the affected area will be blocked in the crown outline. Third, the proportion of the affected area will be estimated in 5 percent classes and recorded.

When the two persons disagree in their estimates, they will discuss their reasons for their rating. Either one will change a rating or an average will be determined and the class of the estimate will be recorded. The differences may be due to differences in crown conditions, the estimate of the person or both.

Dead branches, crown dieback, and missing branches or areas where foliage is not expected to be are deleted from the estimate. On closed crown trees, foliage transparency is estimated for the whole crown, excluding large openings where foliage can not be present because of lack of branches. On open crown trees, foliage transparency is measured on the foliated portions of the branches. The primary purpose of the measurement is to standardize measurements of foliage loss from disease or insect defoliation. Tree species and age seem to effect foliage transparency because of characteristic branch overlap and foliage placement on the branches. Poorly growing trees also have sparse branches and foliage.

Expected precision: Recorded measurements must be within 2 percentage classes (approx. 10%) when remeasured. Greater differences are considered errors, however, a third measurement is required to determine which measurement is in error. The error frequency must be 10% or less for the data to be acceptable, unless confirmation is made that the original measurements were correct, that is, the remeasurement was in error.

Limitations: Measurement errors may occur from several sources. Portions of the crown may not be clearly visible. As defoliation increases, branches and seeds may interfere with foliage estimates. Some variation occurs from judgement when to include or exclude holes, that is areas without branches, in the overall estimate.

Causes For Change

Foliage transparency is the most variable crown condition. Most frequent changes occur from direct damage and removal of foliage.

Increase: Foliage transparency increases, that is, foliage is reduced from:

1. Insect defoliation.
2. Diseases.
3. Previous stresses.
4. Declining tree vigor.
5. Decreased needle retention of conifers.
6. Decreased size of leaves or needles.
7. Loss of branches decreases foliage overlap.
8. Loss of adjacent trees may affect the estimate.

Decrease: Foliage transparency may decrease with reduction of stand density and followed by addition of new branches to create overlap. Of course, foliage transparency will increase following previous defoliation if the tree does not die.

Persistence: Foliage transparency is one of the most rapidly changing variables measured in the crown of the tree. Wind, frost, and hail can change foliage transparency in hours. Insect defoliation changes may be measurable days apart. Diseases may contribute to steady decline of foliage during a growing season. Defoliation of evergreens may contribute to foliage transparency change for more than a year. Poor site associated with higher foliage transparency may persist for the life of the tree.

Intended Use

Foliage transparency is used as a measurement of defoliation. Usually, serious adverse effects on the tree are not expected until more than one half of the foliage is lost. Thus, broad classes are used to describe stresses from defoliation. However, stressed trees from drought, diseases, nutrient deficiencies, and pollution are likely to have more transparent crowns for several years. Tree maturation may also reduce increase foliage transparency.

Shared Attributes

Foliage transparency does not include any other crown measurement. However, it is included in the crown density estimate. Since foliage blocks transmission of light through the crown, the attribute measured in crown density, it contributes heavily to the measurement.

Visual Damage Symptoms

Visual damage assessment is used to determine probable cause of stress. Crown condition indicators describe the crown as it appears to the observer. However, crown may decline after some serious stress, such as defoliation, discoloration and other damage. These damages need to be recorded when they occur, since the signs may be lost within a year and it would be difficult to reconstruct it when crown conditions decline. One must remember, however, that crown condition may be effected also from a variety of damage below the ground and on the trunk below the crown. The crews are instructed to record damage when certain minimum requirements are met, or when the observer believes that the damage will reduce growth or life expectancy. The whole set of damage codes are provided in Appendix III as part of the National Forest Health Monitoring Field Manual.

Visible major damage is recorded by location and probable cause. Up to three major damages may be recorded for a tree. The emphasis in the damage assessment is not to conduct an inventory of signs and symptoms on trees in the forest, but to provide a possible explanation when a tree declines or dies.

Summary

Crown Position: Crown position class rating describes tree vigor in relation to sunlight received and a tree's position in relation to the neighboring trees. The 5 classes are used: Open grown, dominant, codominant, intermediate, and suppressed.

Live Crown Ratio: Live crown ratio is the percent of total tree height that supports live foliage. Dead top is excluded from tree height. Likewise, dead lower branches are not included as part of the live crown.

Crown Diameter: Crown diameter is the average horizontal distance between widest point of the crown and its perpendicular axis measured on the ground at the drip-line of branch tips. When an unusually long branch occurs on a side of tree, the next longest branch is chosen.

Crown Density: Crown density represents the amount of branches, foliage, and reproductive structures that block light visibility through the crown. The crown for this estimate is bilaterally symmetrical perimeter of the live and dead branches including spaces between branches and large open areas. Dead top is part of the crown, but dead lower branches are excluded.

Crown Dieback: Crown dieback is defined as branch mortality that begins at the terminal portion of branch and proceeds toward trunk. When whole branches are dead in the upper crown, without obvious signs of damage such as animal damage or breakage, it is assumed to have died from the terminal down. Large dead branches without fine twigs (Less than 1-inch branches) are snag branches, or old dead branches and are not included as dieback. Dead branches in the center and lower crown or below the live crown are assumed to have died from competition or shading and are not considered dieback.

Foliage Transparency: Foliage transparency is defined as the amount of skylight visible through the foliated portion of the crown or branch. The dead parts of crown are excluded. The crown perimeter is a line following the contours of major branches, excluding the large gaps between branches. Likewise, large open areas within the crown are excluded if foliage is not expected to occur there. Smaller similar openings are considered part of the

Visual Damage Symptoms: Visible major damage is recorded by location and probable cause. Up to three major damages may be recorded per tree. The emphasis in damage assessment is not to conduct inventory of signs and symptoms on trees in the forest, but to provide a possible explanation when a tree declines or dies.

DATA QUALITY CONTROL

Field measurements usually are taken by many individuals and crews. To maintain measurement quality so that all the measurements are comparable for analysis, training and certification is required for all field personnel and visual aids are provided for reference and year-to-year standardization of trainers. Field measurements are repeated on about 10 percent of the measurements to determine variability between crews within a state, and between states and regions.

MEASUREMENT UNITS AND PRECISION OBJECTIVES

The basic measurements are crown codes for crown position, nearest 1 ft. for crown diameter, and 21-percentage classes (Table 1) for live crown ratio, crown density, crown dieback, and foliage transparency.

Table 1. Percentage classes used in National Forest Health Monitoring

No.	Class range	Code
1.	0%	00
2.	01 - 05%	05
3.	06 - 10%	10
4.	11 - 15%	15
5.	16 - 20%	20
6.	21 - 25%	25
7.	26 - 30%	30
8.	31 - 35%	35
9.	36 - 40%	40
10.	41 - 45%	45
11.	46 - 50%	50
12.	51 - 55%	55
13.	56 - 60%	60
14.	61 - 65%	65
15.	66 - 70%	70
16.	71 - 75%	75
17.	76 - 80%	80
18.	81 - 85%	85
19.	86 - 90%	90
20.	91 - 95%	95
21.	96 -100%	99

Note: The class code is the highest percentage in that class, except for 96-100% when 99 is used.

The precision objectives state the level of expected precision (Table 2). The actual precision of measurements is determined from remeasurements of a subset of field measurements. When remeasurements indicate unacceptable field data, the whole measurement process is evaluated to determine sources of deviation, the necessary mitigating measures to improve data, or changes needed for precision objectives.

Table 2. Measurement Units and Precision Objectives Summary.

Crown Condition Indicator	Measurement Units	Acceptable Deviation	Acceptable Error Rate
Crown Position	5 classes	+/- 1 class	1 out of 10
Crown Diameter	1 foot	+/- 3 ft	1 out of 10
Live Crown Ratio	5% classes	+/- 2 classes	1 out of 10
Crown Density	5% classes	+/- 2 classes	1 out of 10
Crown Dieback	5% classes	+/- 2 classes	1 out of 10
Foliage Transparency	5% classes	+/- 2 classes	1 out of 10

TRAINING

Training is necessary for standardization of methods that different crews use to measure crown condition indicators. When different instructors are used in training, the instructors themselves should standardize their methods before teaching them to the crews. Training should be annual for all the crews to assure consistency from one year to the next.

A training session should begin with a discussion of definitions and purpose of measurements. Visual aids should be used to explain the methods. Afterward, the same methods should be demonstrated in the field. Special emphasis should be given to details that help gaining confidence and increase efficiency.

Lecture

The concepts used to measure crown condition indicators are best explained in classroom environment where various visual presentations can be made. This guide should be used as a reference. The guide is structured in the order needed to do measurements, and therefore, it may be used as a work-book. About two hours are needed to cover all the crown condition measurements.

Field Demonstration

The basic principles of crown rating are demonstrated in the field by the trainer. They actively demonstrate the method for each measurement and provide the measurement values. The first time a measurement is presented for a tree, the instructor gives the value at the end of discussion. The students are asked to determine their values first, then the instructor gives his value and discusses differences between student values and his. About an hour is needed for a formal field demonstration.

Field Practice

About 50 trees, of wide range of species and crown condition, are needed for each person to learn the concepts of crown condition rating. A minimum of two trained crown raters are needed to determine crown measurements and to demonstrated the variability between individuals. Small group with less than 10 persons may be trained by choosing sample trees while walking through a stand. Large groups are better trained by pre-selected 5-tree clusters and the crews practicing on 10 clusters. An experienced trainer must accompany each group to properly explain the rating system.

Small group training: The trainer selects a tree and asks the students to rate it. Then the two instructors give their measurement values, agree on final value, and discuss differences between student values and the final value. Usually, about 5 measurements are needed to confirm students understanding of concepts. Thereafter, about three trees for each major crown characteristic group should be rated (pine, spruce/fir, hemlock, maple, ash, oak, aspen/birch, hickory, beech, etc). Whenever possible, all species should be rated at least once. However, many of the species will not be present at any one location.

Large group training: Two or more trainers select sufficient number of 5-tree clusters to occupy all groups of students at the same time (This assumes that sufficient number of qualified trainers are available to provide one per group). A tag is placed on a side of the tree from where it will be rated. It is important that all the rating is done from the same point of view to assure that all students rate the same visual condition. The measurement values may be recorded on the tag, or preferably, provided to the assistant instructor. Actual field forms are used by the students to record their values. Then the instructor reports the actual values determined by the instructors. Any differences exceeding acceptable levels of variability should be discussed. The crown rating should continue as long as students report unacceptable differences.

Certification

A test is given at the end of the field training. Each student must execute at least 20 measurements for each crown condition indicator. This provides documentation of student proficiency. Test values should be reviewed at the end of the test. Any unacceptable values should be reviewed by the student and when disagreement persists, explanation for the instructors values should be discussed. Students are certified as qualified crown condition raters with 2 or less errors (ratings exceeding acceptable variability) for the 20 measurements for each indicator.

Retraining

Personnel that have done crown condition indicator measurements previous year do not need the theoretical discussions in the classroom, but are encouraged to take the field demonstration and practice sessions before taking the certification exams.

VISUAL AIDS

Visual aids are an important part of the standardization effort. In the beginning, the novice learns proper procedures for the measurements and gains confidence. During the field season, visual aids provide quick refreshers after delays between training, or prolonged inactivity. The specific visual aids are the Crown Grid and Crown Density/Foliage Transparency Standards (Appendix II).

The Crown Grid is a transparent plastic sheet with printed equal-lateral squares. It is held in front of the eyes while looking at the tree crown. The arm is extended or shortened to accommodate the whole crown within the grid. The crown outline is drawn with erasable marker, then any damage in the crown, such as crown dieback area is marked out. The proportion of crown dieback squares in relation to the total number of squares for the crown determines the percentage of crown dieback.

The Crown Density and Foliage Transparency Standard provides shaded samples of black and white cells in 5-percent classes. These are designed to estimate the amount of light penetrating the crown to the observers eye. The observer matches the darkness of the square to the tree crown and determines the percentage class. (The earlier standards for crown density were separate from foliage transparency). It is important to note that foliage transparency estimates the proportion of light penetrating tree crown that is present, while crown density is the inverse percentage, that is, the amount of light blocked by the crown and its missing parts.

FIELD PROCEDURES

Crown rating requires a good visual view of the crown. Two persons are more likely to see the whole crown than one, and the discussion and negotiation between the two persons is likely to reduce errors and reduce extreme measurements. However, both persons must be moving frequently, to separate the crown under observation from the other crowns around and beyond it. Search for the best view is important, and usually is accomplished by small lateral movements. The visibility of the top of the tree improves with distance from the tree, but this must be balanced against the decreased visibility of the crown from competing vegetation.

Sequence of Measurements

The sequence of measurements will be determined by the field tally form, or the portable data recorder sequence demand. Crew efficiency will be maintained when vantage points are used to complete all the measurements, before proceding to the next vantage point. The recommended order of measurements are: crown position class, live crown ratio, crown diameter, crown density, crown dieback, and foliage transparency.

Team-work

Variability between persons of estimated measures are reduced by the requirement to record the average from at least two estimates. This method reduces also the probability of errors caused by wrong measurements, such as rating an adjoining tree, or using crown density percentage estimate for foliage transparency.

Sources of measurement differences include boundary estimates for the crown and the affected area, ability to detect the damage, and the raters ability to estimate crown conditions. Differences between the observers can be minimized by open and frequent communication between crew members making the estimate. Consistency and quality are also encouraged by changing observation positions and repeating estimation procedures.

REMEASUREMENTS

Data quality is determined from field remeasurements. At least 5 percent of all the measurements for each crown condition indicator should be remeasured. These remeasurements will confirm that the data quality objectives are being met, or if not, provide an opportunity to assess the training program, crew qualifications, and acceptability of measurements for analysis. The greatest variability is expected between crews trained by different instructors, then between crews trained by the same instructor, and the least difference between remeasurements by the same crew.

Remeasurements may differ because of weather conditions, particularly light, and when sufficient time passes to allow changes in the tree itself. Remeasurements done immediately after the original are the best to determine variability among persons and this procedure is used in the training and certification program. All remeasurements should be completed less than two weeks after the trees were originally rated. The original measurement is assumed to be the correct one until proven to be in error. Third measurement is needed to determine which one is acceptable. Remeasurement differences and other supporting documentation will be used to delete measurements from a crew.

VISUAL CROWN RATING (VCR) MODEL

The Visual Crown Rating (VCR) model describes the condition of upper canopy trees by combining measurements (live crown ratio, crown diameter, crown density, crown dieback, and foliage transparency) considered to be indicators of survival potential, growth, and vigor. The complete model is provided in Appendix I.

The VCR model places upper canopy trees in one of four condition classes: good, average, poor, and very poor. Trees with less than 50% foliage transparency are evaluated for live crown ratio, crown diameter, crown density and crown dieback. Three broad classes are established for each one of these measurements as follows:

Table 2. Crown condition classification criteria

	Crown Condition Classes		
Indicator	Good Class 1	Average Class 2	Poor Class 3
Live Crown Ratio	40% or more	20% - 35%	5% - 15%
Crown Diameter*	55% or more	26% - 54%	1% - 25%
Crown Density	55% or more	25% - 50%	5% - 20%
Crown Dieback	0 - 5%	10% - 25%	30% or more
Foliage Transparency	0 - 45%	50% - 70%	75% or more

* The crown diameter percentage is based on an assumed normal crown diameter of a 5-inch diameter tree or larger. The normal crown diameter may be an average diameter of dominant trees in forest health monitoring survey, or a diameter established from other sources.

Temporary defoliation by insects and diseases induce stress on the tree and prevent proper assessment of crown density and dieback. Therefore, a submodel is created where the crown condition values for density and dieback are replaced with the transparency value.

The VCR model tree vigor classes are as follows:

Good - all indicators are class 1, or only one class 2, and no class 3.

Average - not as good as above; many combinations of classes 1 and 2, but none are class 3.

Poor - at least one indicator is class 3, but never all four indicators.

Very poor - all four indicators are class 3; living trees that do not have live branches larger than 1 inch diameter are included here.

Limitations

This model is proposed by the authors on the basis of specific data for sugar maple, loblolly pine, and shortleaf pine. Only general field observations and experience was available for the major commercial tree species. Much caution should be used for other species less frequently encountered in the forest, since minimal knowledge or experience for crown indicator values is available. The crown condition assessment classes assume that all the species are alike, however, all trees are different and they respond differently to stresses. Eventually, when more precise information becomes available, tree specific VCR's may be possible. The known values for intermediate and suppressed trees are too poorly known, that even a generalized VCR model is not appropriate. The VCR model should be considered experimental until confirmed in the field.

BACKGROUND LITERATURE

Anderson, R. L.; Belanger, R. P. 1987. A crown rating method for assessing tree vigor of loblolly and shortleaf pines. In: Phillips, Douglas R., Comp. Proceedings of the fourth biennial southern silvicultural research conference, 1986 November 4-6, Atlanta, GA. Gen. Tech. Rep. SE-42. Asheville, NC: Southeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture. p.538-543.

Anderson,R.; Burkman, W.; LaBau, V.J.; Millers, I.; Miller-Weeks, M.; Schomaker, M. 1992. Crown classification. In: Forest Health Monitoring Field Methods Guide - '92, XXX compiler, Las Vegas, NE: Environmental Protection Agency, and U.S. Department of Agriculture, Forest Service. p. XXX-XXX.

Belanger, R. P.; Anderson, R. L. 1989. A guide for visually assessing crown densities of loblolly and shortleaf pines. Research Note SE-352, Asheville, NC: Southeastern Forest Experiment Station, Forest Service. U.S. Department of Agriculture. 2 p.

Belanger, R. P.; Zarnoch, S. J.; Anderson, R. L.; and Cost, N. D. 1991. Relation between visual crown characteristics and the periodic radial growth of loblolly pine trees. (Abstract) Southwide Forest Disease Workshop, June 1991. Durham, NC: Duke University. 1 p.

Ciesla, W. M.; Hildebrandt, G. 1986. Forest decline inventory methods in West Germany: opportunities for application in North American forests. Methods Applications Report No. 86-3, Ft. Collins, CO: Forest Service, U.S. Department of Agriculture. 31 p.

Innes, J. L.; Landmann, G.; Mettendorf, B. (In preparation) Consistency of observations of forest tree defoliation in three European countries. Manuscript submitted to Journal of Environmental Monitoring and Assessment.

Millers, I.; Lachance, D.; Burkman, W.G.; Allen, D.C. 1991. North American sugar maple decline project: organization and field methods. General Technical Report NE-154, Radnor, PA: Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture. 28 p.

Millers, I.; Miller-Weeks, M.; Cooke, R.; Cox, S. 1990. New England forest health monitoring: Crown rating guides. Appendix VI. In: New England Forest Health Monitoring - Methods Manual for Field Measurement, Compiled for USDA Forest Service and EPA Environmental Monitoring and Assessment Program by: Dwire, K.; Huntley, B.; Miller-Weeks, M.; Brooks, R., Durham, NH: Forest Service, U.S. Department of Agriculture. 11 p.

Millers, I.; Miller-Weeks, M.; Mielke, M. 1986. Cooperative survey of red spruce and balsam fir decline and mortality in the Northeast: Symptoms and trends. Durham Field Office Workplan, Revised 6/13/86, Durham, NH: Northeastern Area, Forest Service, U.S. Department of Agriculture. 24 p.

Toumey, J. W.; Korstian, C. F. 1947. Foundations of silviculture upon ecological basis. 2nd. Ed. New York, NY: John Wiley and Sons, Inc. 468 p.

USDA Forest Service. 1991. Eastern forest health monitoring field measurements guide. Compiled by Chojnacky, D.C., Forest Survey, Intermountain Research Station, Ogden UT: Southeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture. 84 p.

Weiss, M. J.; McCreery, L. R.; Millers, I.; Miller-Weeks, M.; O'Brien, J. T. 1985. Cooperative survey of red spruce and balsam fir decline and mortality in New York, Vermont, and New Hampshire, 1984. NA-TP-11, Broomall, PA: Northeastern Area, Forest Service, U.S. Department of Agriculture. 53 p.

Zedacker, S.; Nicholas, N. 1990. Quality assurance methods manual for forest site classification and field measurements. EPA/600/3-90/082, Corvallis, OR: Environmental Research Laboratory, U.S. Environmental Protection Agency. 47 p.

APPENDIX I

National Forest Health Monitoring

THE VISUAL CROWN RATING MODEL (VCR)

United States
Department of Agriculture

Forest Service

Northeastern Area
Forest Health Protection
and
Southern Region
Forest Pest Management

VISUAL CROWN RATING MODEL
FOR UPPER CANOPY TREES IN THE EASTERN UNITED STATES

May, 1992

Prepared by: Robert L. Anderson, Forest Health Monitoring Program Leader Southern Region, Asheville NC; William G. Burkman, Forest Health Monitoring Coordinator Northeastern Area, Radnor PA; Imants Millers, Entomologist, Northeastern Area, Durham NH; William H. Hoffard, Entomologist, Southern Region, Asheville NC.

Abstract

In the systematic plot network of the National Forest Health Monitoring Program, several crown measurements are collected to describe the condition of the trees. A model was developed using estimates of live crown ratio, crown diameter, crown density, crown dieback, and foliage transparency to assess overall condition of the upper canopy trees. Procedures are presented in this report that integrate and evaluate these crown variables to determine a rating class for upper canopy trees in the Eastern United States.

Introduction

In Europe, several crown measurements are used in combination to describe the visual condition of a tree (Innes and Boswell 1988). A similar desire was expressed at the Forest Health Monitoring Reporting meeting at Raleigh, NC (July 1991). A committee was formed to see if a model could be developed to integrate the different crown measurements taken on trees in the detection plots. In response to this request, the authors have developed the model with assistance and suggestions from many other people experienced in tree crown rating.

The first job was to define the task. We could not find anyone that could define tree or forest health in terms of a model. We explored several approaches such as developing a model that would predict growth of individual trees. With some field testing this appeared to be a possibility. However, it became apparent that in 4 or 5 years we would have the real growth rates from the remeasured trees on the plots. Why develop a model that would predict the growth with less precision than the actual measurements? Therefore, we agreed that our mission is to develop a model that describes the visual condition of the tree as observed during the year of field data collection. If possible, these observations of individual trees, then could be incorporated into a stand model.

Our objective became the development of a visual tree condition model defined as follows:

Visual Crown Rating (VCR) model is a description of the visual condition of a tree. The rating may be related to survival potential, growth and vigor, but the primary objective is to describe the relative visual condition of the tree.

Methods

The first step was to evaluate all of the indicators currently used on the Forest Health Monitoring Detection plots. The following indicators were selected from the list:

1) Tree Species
2) Tree Position
3) Live Crown Ratio
4) Crown Diameter
5) Crown Density
6) Crown Dieback
7) Foliage Transparency

Tree species is an important consideration for model development. Some attributes, such as normal crown diameter and foliage transparency differ between species.

Crown position of trees becomes important when average stand conditions, or forest conditions are described. Intermediate and suppressed crown class trees are already known to be less vigorous, and more likely to die. Forest stand management models already consider these conditions. Because of this, the Visual Crown Rating model uses upper canopy trees only (open grown, dominant and codominant crown classes). Normally, these trees are expected to have good visual appearance, occasionally reduced to average because of competition from neighboring trees. Field measurements for crown ratio, crown density, crown dieback and foliage transparency are recorded in 5-percent classes. Crown diameter was recorded to the nearest one foot for both, the widest point and its perpendicular axis. The proponents of the model considered a regression approach, but discarded it in favor of a three class system for each variable. This was done because the regression models tested did not go a good job of predicting what was observed in the field. Each variable was examined to identify logical points of separation that represent the three condition classes: good, average, and poor. The following descriptions of the variables, measurements, and condition classes were agreed upon:

Crown Ratio: The crown ratio is the proportion of live tree crown in relation to the total height of the tree. In the field, measurements were recorded in 5-percent classes (Conkling and Byers 1992). The three separation classes were established on the basis of field observations by the authors. Some pruning studies have shown that up to two-thirds of a tree height (one-third with branches) may be void of branches without reduced height growth. This was taken as the lower limit of a good crown ratio (live crown ratio percentage class of 40% and better). The remaining two thirds were divided equally between average (percentage classes 20% to 35%) and poor live crown ratio (percentage classes 5% to 15%).

Crown Density: Crown density is the combination of foliage, branches, and reproductive structures that block light visibility through the crown. The crown is assumed to be a stylized representation of a normal forest grown tree with each species having its own crown form. Stand density and damage to the branches and foliage reduces crown density. Measurements are visual estimates in 5-percent classes. Field observations and growth data for shortleaf and loblolly pine indicate that about one half of a normal crown or more (percentage class 55% and better) provides good growth (Anderson and Belanger 1987, Belanger et al. 1991, Belanger and Anderson 1989). Absence of data for other species and our general field observations suggested that this could be used as the lower limit for a good crown density. Again, the remaining one half was subdivided using the shortleaf and loblolly pine data to arrive at the proposed average (percentage classes 25% to 50%) and poor (percentage classes 5% to 20%) crown density classes.

Crown Diameter: Crown diameter is the average of the crown diameter measured at the widest point and the diameter measured at the perpendicular axis to the first measurement. Measurements are recorded to the nearest 1 ft. Available data for natural stands of loblolly and shortleaf pine indicated that the average crown diameter of 20 ft or more was excellent, 10 to 20 ft good, 5 to 10 ft moderate and less than 5 ft poor (Chojnacky 1991, Belanger et al. 1991). Several hardwood species such as oaks and maples have larger crowns, while birches and poplars have small crowns. Consequently, we propose to use proportions of normal healthy crowns for the species as the condition class values. Trees with 55% or more of normal crown diameter are considered class 1; trees with 26% to 54% of normal crown diameter are class 2; and, trees with 25% or less of normal crown diameter are class 3.

. The normal crown widths will be determined from field measurements of dominant trees in the plots. When plots do not provide sufficient number of sample trees, the recommended values will be obtained from specialists familiar with that species and/or similar species.

Crown Dieback: Crown dieback is defined as branch mortality that begins at the terminal and progresses toward the trunk of the tree. It is considered an indicator of unhealthy condition caused by insect or disease damage, or the result of some current or previous environmental stress. The measurement is a visual estimate in 5 percent classes, except that a "0" class is used to reflect a total absence of crown dieback. The condition class limits are based on our observations in the field, and data from the North American Sugar Maple Decline Project (Millers et al. 1991). Since some crown dieback, at least a few twigs, are present on most hardwoods, up to 5% dieback was permitted as a good condition tree. Average trees are allowed to have up to 25% crown dieback, since seed years and other 'normal' stresses are thought to cause fluctuations within these limits without major decline of the tree. More extensive dieback is considered abnormal, indicating poor condition of the tree.

Foliage Transparency: Foliage transparency is defined as the amount of skylight visible through the live branches that normally would be foliated. It represents spacing and size of foliage on the branches, overlapping of branches in the crown, and defoliation caused by insects and disease (Millers et al. 1991). The measurement is a visual estimate in 5 percent classes. Normal variation among species is large. Some species, such as sugar maple and many conifers have normal foliage transparency in the range of 10 to 15%. Other species, such as poplar, birch and compound-leaved trees may be normal with 30 to 40 % foliage transparency. Until better information becomes available, we set the limits that foliage transparency percentage classes up to and including 45% do not show any likely stress; percentage classes of 50% to 70% may be under moderate stress; and, percentage classes of 75% and larger foliage transparency indicate severe stress.

For modeling purposes, we are required to have two separate models based on transparency. Insect and disease defoliation is likely to mask dead terminal twigs and interfere with density and dieback estimates. We are proposing that the basic model uses all 5 crown condition indicators, but when transparency reaches percentage class of 50% or higher, density and dieback estimates are replaced with the transparency estimate class value.

Visual Crown Rating Model

In summary, the following crown measurement classes were used to develop the Visual Crown Rating of tree crowns.

Measurement	Class 1	Class 2	Class 3
Crown Ratio	40% or more	20-35%	5-15%
Crown Diameter	55% or more	26-54%	1-25%
Crown Density	55% or more	25-50%	5-20%
Crown Dieback	0-5%	10-25%	30% or more
Foliage Transparency	0-45%	50-70%	75% or more

In the construction of the model, the first four class values (ratio, diameter, density, and dieback) are combined to arrive at the Visual Crown Rating set of numbers (Theoretical Assessment of Visual Crown Systems to Establish Crown Condition Ratings of Upper Canopy Trees Table). A decision flow chart (Visual Crown Rating - Transparency less than 50 Percent) is also provided for visual explanation on how the various measurements are used to reach VCR decisions (Figure 1).

Since defoliation is likely to interfere with crown dieback and crown density measurements, because of difficulties of separating live branches from dead branches, trees with more than 50% transparency have a separate Visual Crown Rating model. The qualitative classes of crown conditions for trees with none to light defoliation (transparency percentage class lower than 50%)

RULES FOR DETERMINING VCR RATING

1. Good (VCR 1) - all measurements are class 1, or three of classes 1 and one 2; no measurement falls in class 3.

2. Average (VCR 2) - Not as good as above; many combinations of class 1 and 2, or all class 2, but none are class 3.

3. Poor (VCR 3) - at least one measurement falls in class three, but never all four.

4. Very Poor (VCR 4) - all four measurements are in class 3; in the future, all live trees without branches will also be included here.

When foliage transparency percentage class is 50% or greater, the damage class value replaces both the crown density and the crown dieback classes (Visual Crown Rating with Defoliation - Transparency 50% or more). For example, a Good VCR tree (1,1,1,2) becomes an Average VCR tree with 50% foliage transparency (1,1,2,2). The same tree with heavy defoliation of 75% or greater foliage transparency would be rated poor (1,1,3,3) for that year.

Field Evaluation

The VCR model was briefly tested by a group of 4 specialists in the field at Bent Creek, NC. One set of evaluations were made on 10 shortleaf pines growing in a park-like environment, thus in dominant/codominant crown class. The general trends of the crown assessments followed the growth at diameter at 4.5 feet, as well as the visual classes estimated by the specialists. Another set of observations were made on various hardwood species in a woodlot nearby. In general, the specialists agreed that the proposed Visual Crown Ratings reflected the condition of the trees. We feel that the classifications work well because the crown measures do reflect the trees true condition, and the broad classes make the estimates of Good, Average, Poor and Very Poor rather easy to categorize.

Future Improvements

Future improvements may occur as more field data are collected. Comparisons between any two years must be made on similar data. However, since the model is only an analytical tool that does not effect data collection, changes should not carry any long term consequences. Some of the most obvious future improvements are likely the addition of new variables or the adjustment of tree condition values to individual tree species (i.e., range of crown diameters). For example, heavy defoliation of tamarack does not seem to have much impact, while similar level of defoliation on hemlock is likely to cause mortality.

Other Applications

One of the most obvious uses of the VCR model could be the development of a STAND VCR MODEL. This model could be used to quantify stand condition values, and therefore changes, that are dependent on visual crown conditions. It could also provide quantitative means of describing declining stands.

The following approach is proposed for further evaluation:

Assign a "5" value to dead trees in a plot or stand. Using the VCR values of 1 to 4 and the 5 for dead trees enables the analysts to classify each tree on the plot or stand from 1 to 5. Using this system, a plot of dead trees would be rated as a 5, and a plot of all good trees would be rated as 1. To properly rate a plot or stand it would require weighting the average based on the percent of trees in each of the classes. Species would also have to be considered in the evaluation procedure. It would be possible to compare the same species on a number of plots but it would not be logical to compare a species such as aspen with loblolly pine or to group species in a given plot. Many species probably have a low or high VCR naturally. It would also be important to consider other factors such as the number of trees of a given species in a plot, tree position, and site quality.

We tried the system on oak for two plots at the Bent Creek Experimental forest. It gave us a stand average VCR of about 1.8. The estimate appeared to match with the visual condition of the dominant and codominant oaks on the site. However, there are many questions to be addressed and considerable testing done before the stand VCR is used. It is beyond the scope and available time of this committee to develop and test a stand VCR.

ASSESSMENTS OF CROWN SYMPTOMS TO ESTABLISH VISUAL CROWN RATINGS (VCR) OF UPPER CANOPY TREES

(USE BASIC VCR WHEN TRANSPARENCY PERCENTAGE CLASS IS 45% OR LESS)

CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	BASIC VCR	TRANSPARENCY	CLASSES	DEFOL VCR
40%+	55%+	55%+	0-5%	1,1,1,1	1	50-70%	1,1,2,2	2
			10-25%	1,1,1,2	1		1,1,2,2	2
			30%+	1,1,1,3	3		1,1,2,2	2
		25-50%	0-5%	1,1,2,1	1		1,1,2,2	2
			10-25%	1,1,2,2	2		1,1,2,2	2
			30%+	1,1,2,3	3		1,1,2,2	2
		5-20%	0-5%	1,1,3,1	3		1,1,2,2	2
			10-25%	1,1,3,2	3		1,1,2,2	2
			30%+	1,1,3,3	3		1,1,2,2	2
	26-54%	55%+	0-5%	1,2,1,1	1		1,2,2,2	2
			10-25%	1,2,1,2	2		1,1,2,2	2
			30%+	1,2,1,3	3		1,1,2,2	2
		25-50%	0-5%	1,2,2,1	2		1,1,2,2	2
			10-25%	1,2,2,2	2		1,1,2,2	2
			30%+	1,2,2,3	3		1,1,2,2	2
		5-20%	0-5%	1,2,3,1	3		1,1,2,2	2
			10-25%	1,2,3,2	3		1,1,2,2	2
			30%+	1,2,3,3	3		1,1,2,2	2
	1-25%	55%+	0-5%	1,3,1,1	3		1,3,2,2	3
			10-25%	1,3,1,2	3		1,3,2,2	3
			30%+	1,3,1,3	3		1,3,2,2	3
		25-50%	0-5%	1,3,2,1	3		1,3,2,2	3
			10-25%	1,3,2,2	3		1,3,2,2	3
			30%+	1,3,2,3	3		1,3,2,2	3
		5-20%	0-5%	1,3,3,1	3		1,3,2,2	3
			10-25%	1,3,3,2	3		1,3,2,2	3
			30%+	1,3,3,3	3		1,3,2,2	3

CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	BASIC VCR	TRANSPARENCY	CLASSES	DEFOL VCR
40%+	55%+	55%+	0-5%	1,1,1,1	1	75%+	1,1,3,3	3
			10-25%	1,1,1,2	1		1,1,3,3	3
			30%+	1,1,1,3	3		1,1,3,3	3
		25-50%	0-5%	1,1,2,1	1		1,1,3,3	3
			10-25%	1,1,2,2	2		1,1,3,3	3
			30%+	1,1,2,3	3		1,1,3,3	3
		5-20%	0-5%	1,1,3,1	3		1,1,3,3	3
			10-25%	1,1,3,2	3		1,1,3,3	3
			30%+	1,1,3,3	3		1,1,3,3	3
	26-54%	55%+	0-5%	1,2,1,1	1		1,2,3,3	3
			10-25%	1,2,1,2	2		1,2,3,3	3
			30%+	1,2,1,3	3		1,2,3,3	3
		25-50%	0-5%	1,2,2,1	2		1,2,3,3	3
			10-25%	1,2,2,2	2		1,2,3,3	3
			30%+	1,2,2,3	3		1,2,3,3	3
		5-20%	0-5%	1,2,3,1	3		1,2,3,3	3
			10-25%	1,2,3,2	3		1,2,3,3	3
			30%+	1,2,3,3	3		1,2,3,3	3
	1-25%	55%+	0-5%	1,3,1,1	3		1,3,3,3	3
			10-25%	1,3,1,2	3		1,3,3,3	3
			30%+	1,3,1,3	3		1,3,3,3	3
		25-50%	0-5%	1,3,2,1	3		1,3,3,3	3
			10-25%	1,3,2,2	3		1,3,3,3	3
			30%+	1,3,2,3	3		1,3,3,3	3
		5-20%	0-5%	1,3,3,1	3		1,3,3,3	3
			10-25%	1,3,3,2	3		1,3,3,3	3
			30%+	1,3,3,3	3		1,3,3,3	3

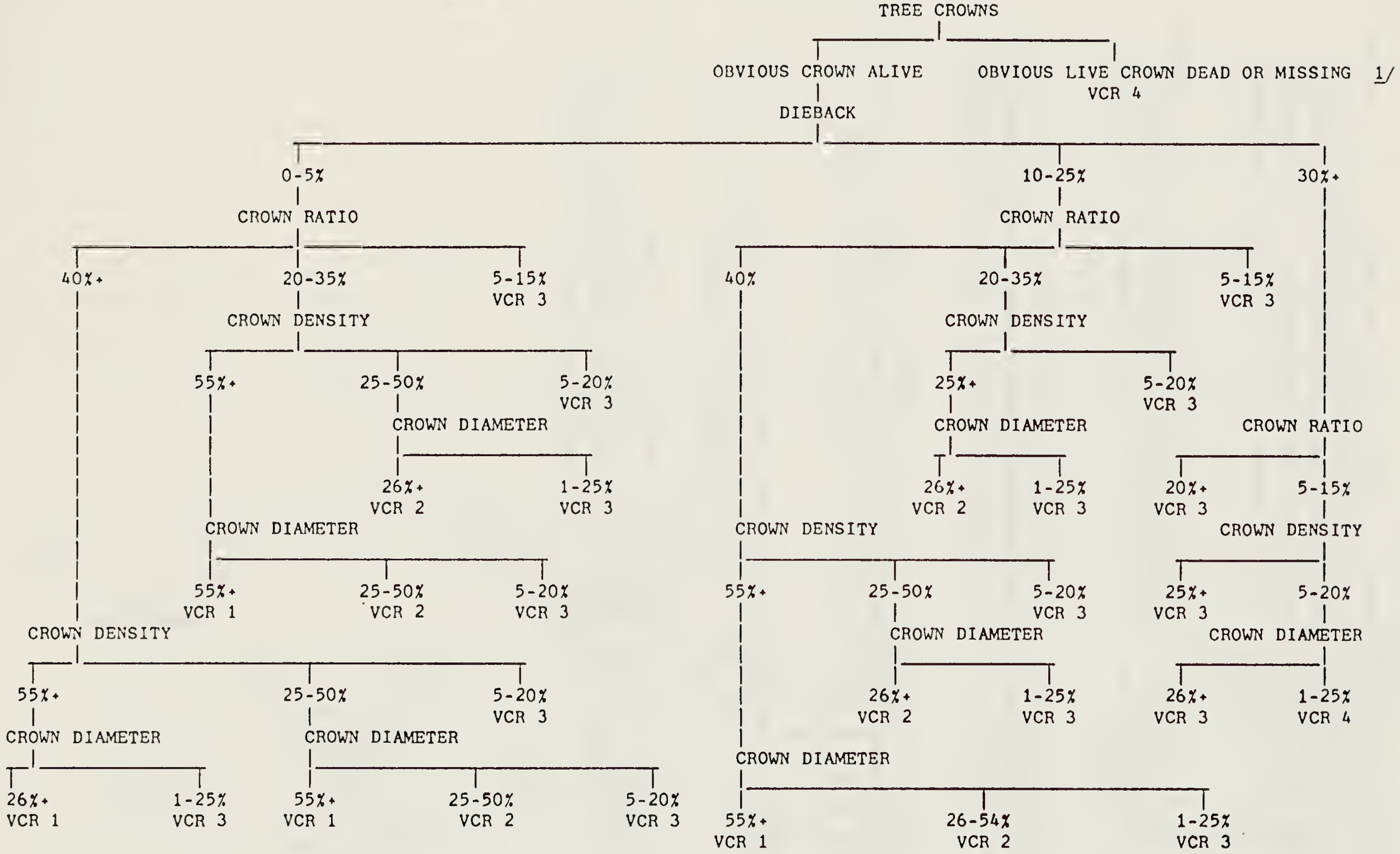
CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	BASIC VCR	TRANSPARENCY	CLASSES	DEFOL VCR
20-35%	55%+	55%+	0-5%	2,1,1,1	1	50-70%	2,1,2,2	2
			10-25%	2,1,1,2	2		2,1,2,2	2
			30%+	2,1,1,3	3		2,1,2,2	2
		25-50%	0-5%	2,2,2,1	2		2,1,2,2	2
			10-25%	2,2,2,2	2		2,1,2,2	2
			30%+	2,2,2,3	3		2,1,2,2	2
		5-20%	0-5%	2,1,3,1	3		2,1,2,2	2
			10-25%	2,1,3,2	3		2,1,2,2	2
			30%+	2,1,3,3	3		2,1,2,2	2
	26-54%	55%+	0-5%	2,2,1,1	2		2,2,2,2	2
			10-25%	2,2,1,2	2		2,2,2,2	2
			30%+	2,2,1,3	3		2,2,2,2	2
		25-50%	0-5%	2,2,2,1	2		2,2,2,2	2
			10-25%	2,2,2,2	2		2,2,2,2	2
			30%+	2,2,2,3	3		2,2,2,2	2
		5-20%	0-5%	2,2,3,1	3		2,2,2,2	2
			10-25%	2,2,3,2	3		2,2,2,2	2
			30%+	2,2,3,3	3		2,2,2,2	2
	1-25%	55%+	0-5%	2,3,1,1	3		2,3,2,2	3
			10-25%	2,3,1,2	3		2,3,2,2	3
			30%+	2,3,1,3	3		2,3,2,2	3
		25-50%	0-5%	2,3,2,1	3		2,3,2,2	3
			10-25%	2,3,2,2	3		2,3,2,2	3
			30%+	2,3,2,3	3		2,3,2,2	3
		5-20%	0-5%	2,3,3,1	3		2,3,2,2	3
			10-25%	2,3,3,2	3		2,3,2,2	3
			30%+	2,3,3,3	3		2,3,2,2	3

CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	BASIC VCR	TRANSPARENCY	CLASSES	DEFOL VCR
20-35%	55%+	55%+	0-5%	2,1,1,1	1	75%+	2,1,3,3	3
			10-25%	2,1,1,2	2		2,1,3,3	3
			30%+	2,1,1,3	3		2,1,3,3	3
		25-50%	0-5%	2,2,2,1	2		2,1,3,3	3
			10-25%	2,2,2,2	2		2,1,3,3	3
			30%+	2,2,2,3	3		2,1,3,3	3
		5-20%	0-5%	2,1,3,1	3		2,1,3,3	3
			10-25%	2,1,3,2	3		2,1,3,3	3
			30%+	2,1,3,3	3		2,1,3,3	3
	26-54%	55%+	0-5%	2,2,1,1	2		2,2,3,3	3
			10-25%	2,2,1,2	2		2,2,3,3	3
			30%+	2,2,1,3	3		2,2,3,3	3
		25-50%	0-5%	2,2,2,1	2		2,2,3,3	3
			10-25%	2,2,2,2	2		2,2,3,3	3
			30%+	2,2,2,3	3		2,2,3,3	3
		5-20%	0-5%	2,2,3,1	3		2,2,3,3	3
			10-25%	2,2,3,2	3		2,2,3,3	3
			30%+	2,2,3,3	3		2,2,3,3	3
	1-25%	55%+	0-5%	2,3,1,1	3		2,3,3,3	3
			10-25%	2,3,1,2	3		2,3,3,3	3
			30%+	2,3,1,3	3		2,3,3,3	3
		25-50%	0-5%	2,3,2,1	3		2,3,3,3	3
			10-25%	2,3,2,2	3		2,3,3,3	3
			30%+	2,3,2,3	3		2,3,3,3	3
		5-20%	0-5%	2,3,3,1	3		2,3,3,3	3
			10-25%	2,3,3,2	3		2,3,3,3	3
			30%+	2,3,3,3	3		2,3,3,3	3

CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	VCR	TRANSPARENCY	CLASSES	DEFOL VCR
5-15%	55%+	55%+	0-5%	3,1,1,1	3	50-70%	3,1,2,2	3
			10-25%	3,1,1,2	3		3,1,2,2	3
			30%+	3,1,1,3	3		3,1,2,2	3
		25-50%	0-5%	3,1,2,1	3		3,1,2,2	3
			10-25%	3,1,2,2	3		3,1,2,2	3
			30%+	3,1,2,3	3		3,1,2,2	3
		5-20%	0-5%	3,1,3,1	3		3,1,2,2	3
			10-25%	3,1,3,2	3		3,1,2,2	3
			30%+	3,1,3,3	3		3,1,2,2	3
	26-54%	55%+	0-5%	3,2,1,1	3		3,2,2,2	3
			10-25%	3,2,1,2	3		3,2,2,2	3
			30%+	3,2,1,3	3		3,2,2,2	3
		25-50%	0-5%	3,2,2,1	3		3,2,2,2	3
			10-25%	3,2,2,2	3		3,2,2,2	3
			30%+	3,2,2,3	3		3,2,2,2	3
		5-20%	0-5%	3,2,3,1	3		3,2,2,2	3
			10-25%	3,2,3,2	3		3,2,2,2	3
			30%+	3,2,3,3	3		3,2,2,2	3
	1-25%	55%+	0-5%	3,3,1,1	3		3,3,2,2	3
			10-25%	3,3,1,2	3		3,3,2,2	3
			30%+	3,3,1,3	3		3,3,2,2	3
		25-50%	0-5%	3,3,2,1	3		3,3,2,2	3
			10-25%	3,3,2,2	3		3,3,2,2	3
			30%+	3,3,2,3	3		3,3,2,2	3
		5-20%	0-5%	3,3,3,1	3		3,3,2,2	3
			10-25%	3,3,3,2	3		3,3,2,2	3
			30%+	3,3,3,3	4		3,3,2,2	3

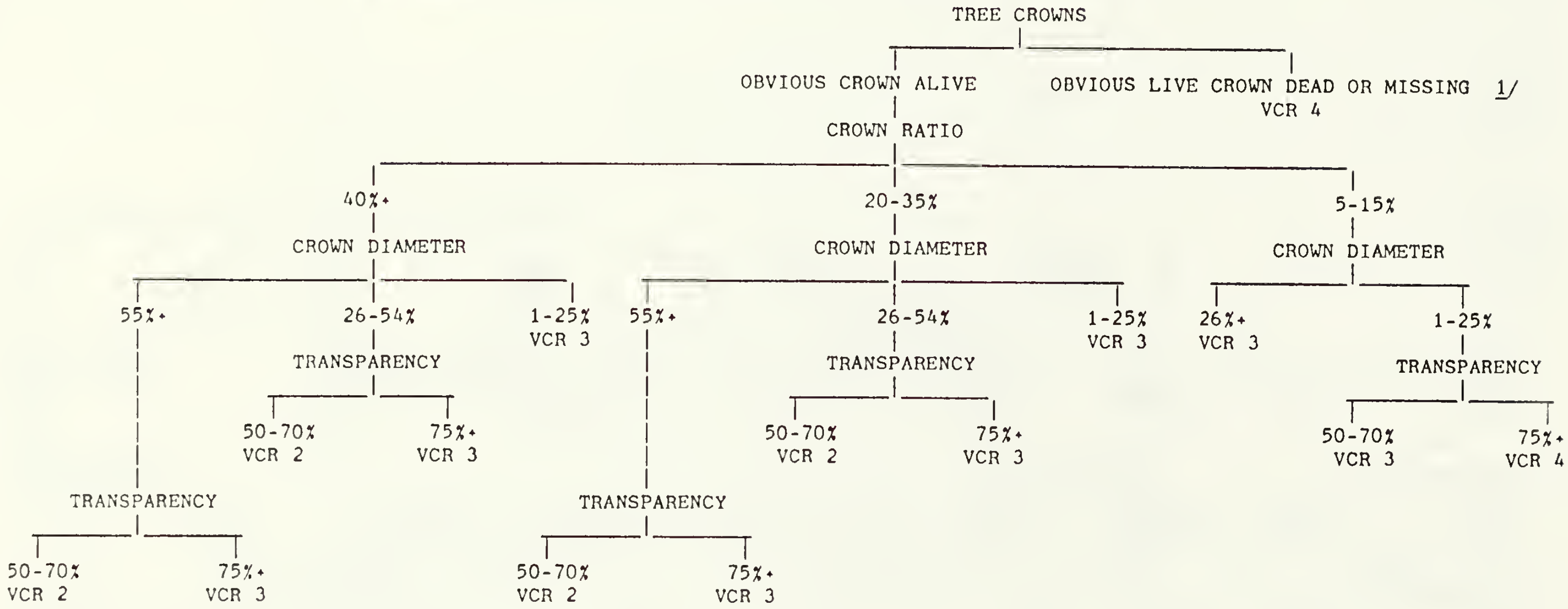
CROWN RATIO	CROWN DIAMETER	CROWN DENSITY	DIEBACK	CLASSES	VCR	TRANSPARENCY	CLASSES	DEFOL VCR
5-15%	55%+	55%+	0-5%	3,1,1,1	3	75%+	3,1,3,3	3
			10-25%	3,1,1,2	3		3,1,3,3	3
			30%+	3,1,1,3	3		3,1,3,3	3
		25-50%	0-5%	3,1,2,1	3		3,1,3,3	3
			10-25%	3,1,2,2	3		3,1,3,3	3
			30%+	3,1,2,3	3		3,1,3,3	3
		5-20%	0-5%	3,1,3,1	3		3,1,3,3	3
			10-25%	3,1,3,2	3		3,1,3,3	3
			30%+	3,1,3,3	3		3,1,3,3	3
	26-54%	55%+	0-5%	3,2,1,1	3		3,2,3,3	3
			10-25%	3,2,1,2	3		3,2,3,3	3
			30%+	3,2,1,3	3		3,2,3,3	3
		25-50%	0-5%	3,2,2,1	3		3,2,3,3	3
			10-25%	3,2,2,2	3		3,2,3,3	3
			30%+	3,2,2,3	3		3,2,3,3	3
		5-20%	0-5%	3,2,3,1	3		3,2,3,3	3
			10-25%	3,2,3,2	3		3,2,3,3	3
			30%+	3,2,3,3	3		3,2,3,3	3
	1-25%	55%+	0-5%	3,3,1,1	3		3,3,3,3	4
			10-25%	3,3,1,2	3		3,3,3,3	4
			30%+	3,3,1,3	3		3,3,3,3	4
		25-50%	0-5%	3,3,2,1	3		3,3,3,3	4
			10-25%	3,3,2,2	3		3,3,3,3	4
			30%+	3,3,2,3	3		3,3,3,3	4
		5-20%	0-5%	3,3,3,1	3		3,3,3,3	4
			10-25%	3,3,3,2	3		3,3,3,3	4
			30%+	3,3,3,3	4		3,3,3,3	4

VISUAL CROWN RATING - Transparency less than 50%



1/ This measure was not collected in 1990 or 91.

VISUAL CROWN RATING WITH DEFOLIATION - Transparency more than 50%



1/ This measure was not collected in 1990 or 91.

Literature Cited

Anderson, R.L.; Belanger, R.P. 1987. **A crown rating method for assessing tree vigor of loblolly and shortleaf pines.** In, Phillips, D.R., comp. Proceedings of the fourth biennial southern silvicultural research conference: 1986 November 4-6; Atlanta, GA. Gen. Tech. Rep. SE-42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 538-543.

Belanger, R.P.; Anderson, R.L. 1989. **A guide for visually assessing crown densities of loblolly and shortleaf pines.** Research Note SE-352. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 2 p.

Belanger, R.P.; Zarnoch, S.J.; Anderson, R.L.; Cost, N.D. 1991. **Relation between visual crown characteristics and the periodic radial growth of loblolly pine tree.** (Abstract) Southwide Forest Disease Workshop, June 1991. Durham, NC.

Conkling, B.L.; Byers G. 1992 **Forest Health Monitoring Field Method Guide.** Internal Document. USDA Forest Service and Environmantal Protection Agency, U.S. Forest Service Laboratory, Research Triangle Park, NC 27709. 18 sections.

Innes, J.L.; Boswell, R.C. 1988. **Monitoring of Forest Condition in the United Kingdom.** Forestry Commission Bull. 88, Alice Holt Lodge, Wrecclesham, Farnham, UK: Forestry Commission. 72 p.

Millers, I.; Lachance, D.; Burkman, W.G.; Allen, D.C. 1991. **North American** Sugar Maple Decline Project: Organization and Field Methods. Gen. Tech. Rep. NE-154. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 26 p.

APPENDIX II

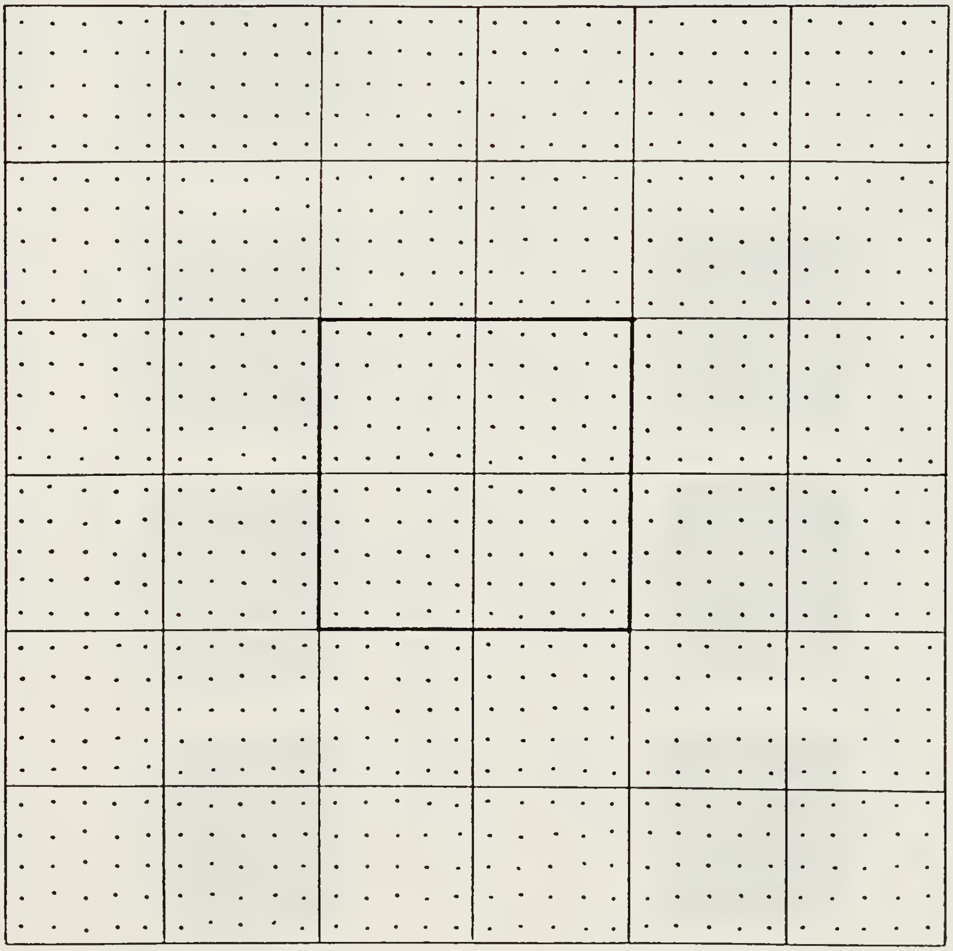
National Forest Health Monitoring

CROWN RATING VISUAL STANDARDS

Various aids are recommended for use in training sessions. These may also be useful during the season, when crown ratings begin after a period of inactivity. The primary purpose of these aids is to provide standardization in methodology between individuals and between years.

Crown Grid

A crown grid is used in training for estimation of crown area. The crown grid was developed from similar grids used to estimate areas on maps. The area does not represent a quantitative unit since its use is intended for determination of proportions. The central square has 100 dots, and each peripheral square has 25 dots. The grid may be copied on a transparency and mounted on a thick plexiglass with clear cellophane tape.



Crown Density and Crown Transparency Standards

The same reference standards are used for both estimates, except that the percentages for one are inverse of the other: crown density measures how dark it is, that is, proportion of light blocked by the tree crown; transparency measures how light it is, that is, proportion of crown allowing the light to penetrate. The crown for density estimates includes dead portions of crown (Not the dead branches below the crown), and the missing parts of the crown, as well as all the large holes in the crown. In contrast, the transparency crown outline follows closely the perimeter of all the large branches, and it excludes large open areas, spaces between branches and dead portions of the crown.

The accompanying sheet may be copied on any standard copier, folded, and used in the field as a reference. Care must be taken that the copier does not eliminate the sparse openings or the sparse dots.

April 2, 1992

Forest Health Monitoring

CROWN DENSITY
and
FOLIAGE TRANSPARENCY
STANDARDS

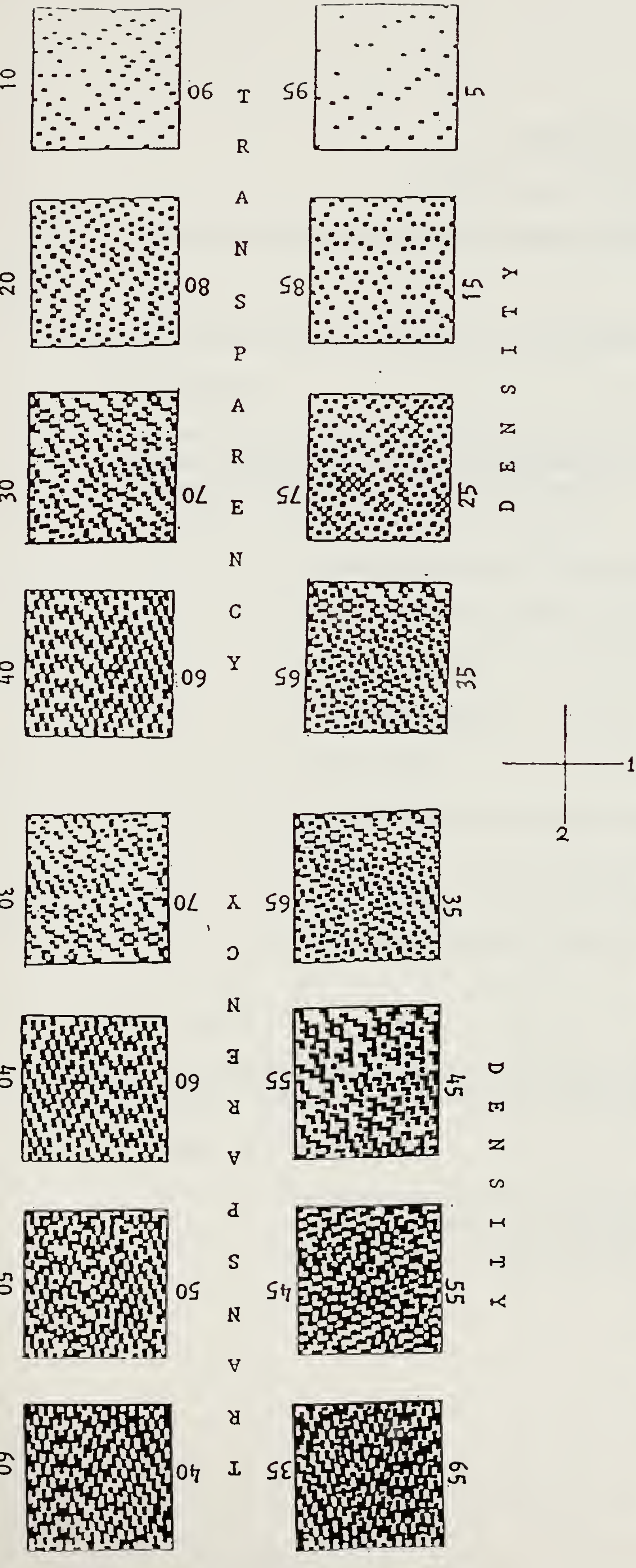
Imants Millers and Robert Anderson
FHP/FPM
U.S.D.A. Forest Service

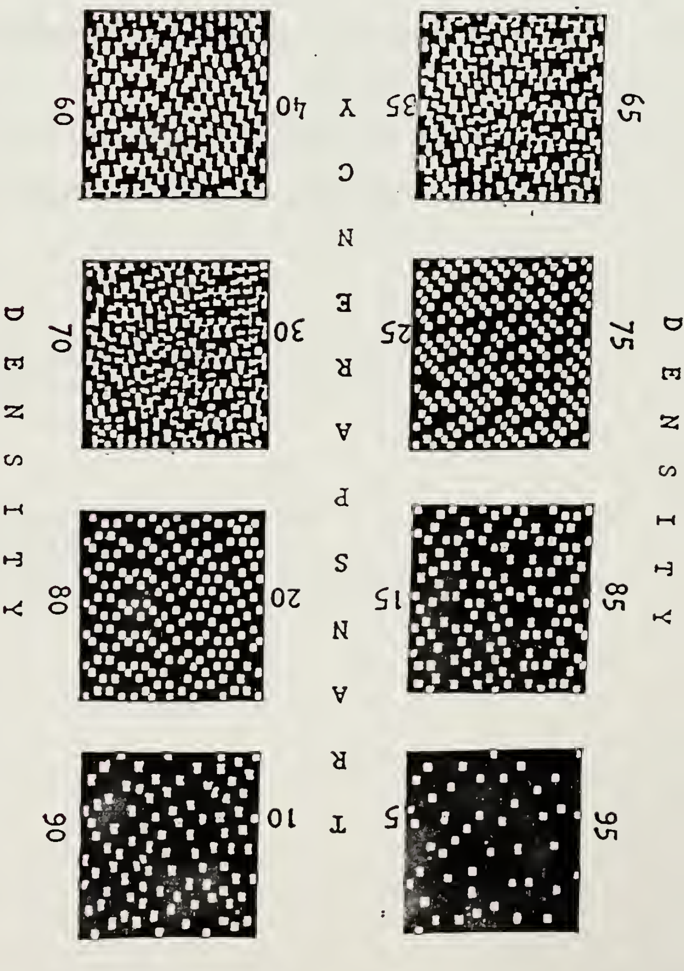
Purpose of these standards: To estimate light penetration through the crown

1. Select most uniform section of crown and match with one of the 8 squares

2. Adjust upward or downward on the basis of the remaining portions of crown

---





APPENDIX III

National Forest Health Monitoring

TREE AND CROWN DAMAGE ASSESSMENT - EXCERPTS FROM FIELD MANUAL - 1992

Copy of relative pages will be included here for reference

Foliage Damage

Some foliage injury may be found on any tree. However, these may impact the crown condition indicators in the current year or in the future when signs or symptoms occur on 30% of the crown with leaves having more than 50% of foliage affected.

Code	Definition
60	**Defoliation** (likely cause of damage is insect feeding)
61	**General discoloration** (mixed colors; includes necrotic foliage)
62	**Pale green foliage**
63	**Yellow-green foliage**
64	**Leaves spotted**
65	**Damaged leaves** (foliage shredded, with holes, or otherwise mechanically damaged)
66	**Distorted foliage** (wrinkled, shrivelled, galled, or otherwise distorted leaves)
67	**Stunted foliage** (stunted or dwarfed foliage; less than 1/2 normal leaf size)

Branch Damage

These signs and symptoms are found only on branches and should be recorded only when they are sufficiently severe to impact any of the crown condition indicators.

Code	Definition
40	**Excessive branching** (indicator of past injury such as top kill
41	**Abundance of seeds or cones** (may cause dieback)
42	**Stunted, dwarfed** (woody stems only, short internodes, chlorotic dwarfs)

Trunk Damage

These signs and symptoms are specific to the trunk only. These are recorded when the expected impact on the tree is sufficiently severe to cause changes in at least one crown condition indicator.

Code	Definition
20	**Crook or sweep** (severe enough to impede growth or affect survival)
21	**Crack or seam**
22	**Swelling** (greater than 1/2 diameter of tree above the swelling)
23	**Leaning** (from partial windthrow or root spring)
24	**Abundance of epicormic branches or water sprouts on trunk or base**

General Damage

The following signs and symptoms may occur on any part of the tree. These should be used when the more specific damage for the various parts of the crown don't match the definitions.

Code	Definition
00	**None**
01	**Dead** (describes part of a live tree)
02	**Open wound** (> 4 sq. in. inner wood exposed)
03	**Closed wound; healed, cankers; lesions** (inner wood not exposed)
04	**Small holes or pinholes** (< 1/2" in diameter; e.g., bark beetle attack/emergence holes)
05	**Broken**
06	**Removed; missing** (other than defoliation by insects; branches or foliage [i.e., pruning])
07	**Rotten branch stubs; excessive swelling at base of dead branches**
08	**Resinosis; bleeding**
09	**Deformed, twisted, curled** (woody stems only)
10	**Galls** (abnormal swellings on main stem or branches)
11	**Imbeded foreign objects** (nail, fence, etc.)
12	**Conks and fruiting bodies**
13	**Fader trees** (bark beetle attacked conifers)
14	**Other than described above** (needs explanation in notes)